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SVIC NOTES

I have been a part of the shock and vibration community in one way or another for more than thirty years. Much of that time has been occupied with the technical information business and, as a part of that, the organization of technical symposia. It is not surprising, therefore, that I have heard most of the arguments for and against participation in conferences and symposia. The basic question is whether the benefits of symposia to a person and/or his organization outweigh the costs. There is, of course, no single answer to this question. Each symposium must be judged on its own merit relative to the needs of the person and organization involved. In some cases, a decision is made as a result of a debate between staff and management. The manager is usually the bad guy and the burden of proof with respect to benefits rests with the staff member. In other cases, there is no opportunity for debate. The answer is negative without recourse, sometimes without an explanation.

There are organizations with a policy of total nonparticipation, while other organizations offer almost unlimited opportunities in the other direction. In my view, both policies are extreme and wrong. In the first case, the engineers and scientists must work in a vacuum with little opportunity to interact with their peers. In the latter, productive research and development effort may well suffer from too much time away from the job. The correct policy lies somewhere in between, where the decision is based on a careful assessment of the benefits versus the cost. In other words, I think that judgments relative to symposia participation are important and should not be taken lightly. Furthermore, these judgments should be taken with equal care by both staff and management.

In the past, members of the shock and vibration community have used Statistical Decision Theory to find a rational solution in the face of uncertainty. This process involves an examination of the probabilities of different results from each of several possible actions. In other words, they examine possible actions and possible results in terms of the product of their knowledge of the situation and their ingenuity in devising strategies. I am certainly not an expert on Decision Theory, but I would ask those who are to consider application of the theory to the symposium attendance problem. Can we use this method to examine all factors bearing on the decision and arrive at some probability of beneficial results? Such a tool, if proven valid, could be of great value to those faced with such decisions.

H.C.P.

EDITORS RATTLE SPACE

OBSOLETE INSTRUMENTATION

Recently I wrote about the lack of engineering courses in our colleges and universities on making physical measurements. At that time I alluded to one cause of this growing trend to exclusive training in computational techniques: a lack of funds to buy test equipment -- both instrumentation and test fixtures.

A recent editorial by George E. Pake of Xerox Corporation on obsolete instrumentation in universities* reminded me of this situation. Pake reviews the state of instrumentation used in the universities for research and training in such basic sciences as chemistry, physics, life, earth, and astronomy. According to his assessment the situation borders on disaster; billions of dollars are needed to modernize the instrumentation in university laboratories. Pake claims that the strength of our technological economy depends on our ability to train quality scientists. Perhaps it can be argued that we are in or should be in a transition from a technological society; however, the growth of computers and other high technology-oriented products does not reflect this trend.

What does it mean to the engineering profession? As with the basic sciences it is essential that engineers use instrumentation and associated techniques to perform their duties of design, development, and analysis. Fortunately the instrumentation involved in engineering does not approach the cost of that used in physics courses. It is my opinion that in the engineering area much necessary equipment could be obtained either by direct donations or at a reasonable cost. The interest shown by the faculty and administration in obtaining equipment will determine whether or not the test equipment in our engineering labs will be modernized. It appears to me that both industry and government are sensitive to these needs. If properly approached and challenged, they will aid in the refurbishment of the instrumentation in our university laboratories.

R.L.E.

**Pake, George E., "Universities' Obsolete Instrumentation," Physics Today, August, 1982, p. 88.*

COHERENT STRUCTURE AND JET NOISE

R.E.A. Arndt* and D.F. Long*

Abstract. This review on aeroacoustics research focuses on the existence of coherent structures in turbulent flow. Their possible influence on sound radiation is also described.

It has been pointed out that the noise level of a turbulent jet scales like the eighth power of velocity and diameter squared ($U_j^8 d^2$); thrust scales with the square of both velocity and diameter ($U_j^2 d^2$). The noise level on an equal thrust basis is therefore proportional to U_j^6, leading to the conclusion that significant reductions in jet noise are possible at the same thrust level by moving larger quantities of air at lower velocity. This is exactly what the high bypass ratio fan jet engine does. Propulsive efficiency is also increased. The fan jet concept is probably the most significant noise reduction concept available and does not rely on any modification to the basic turbulent flow.

This review focuses on one new aspect of aeroacoustics research; i.e. the existence of coherent structures in turbulent flow and their possible influence in the radiation of sound. It has been pointed out [22] that turbulence research has taken a new direction with the discovery that turbulent flows of simple geometry are not as chaotic as previously thought. Early studies [7, 21] relied on relatively simple flow visualization. Researchers are reexamining methods that might lead to meaningful understanding of the physics of turbulence. An in-depth review of this topic is available [8].

The effect of large-scale, coherent structure in turbulent flow on noise radiation is an important problem. Unfortunately current conclusions are as diverse as the number of investigations in progress. Even though a definitive statement on the role of coherent structure in radiation cannot yet be made, many interesting results have been obtained. They point to a better understanding of the physics of noise radiation and could lead to improved methods of noise control.

COHERENT STRUCTURES IN TURBULENCE

Experimental research in the last 20 years has shown that the transport properties of most turbulent flows are dominated by large-scale vortical motions that are not random. The size of these motions, or structures, is comparable to the width of the flow; an underlying vorticity is instantaneously correlated over the spatial extent of the flow (see Figure 1). These structures were undetected during more than 30 years of research. It is evident that the experimental methods, which relied heavily on the interpretation of two-point velocity correlations, were doomed to failure. Time and space averages taken from one or two probes fixed in space tend to smear out the essential features of these structures because the averages are taken over many realizations of different structures in different stages of development [22].

The statistics of turbulent flow can be interpreted to accommodate the existence of coherent structures. An example is the typical set of space-time correlations using two hot wires in the mixing layer of a jet (see Figure 2). As the spacing between the wires increases, the delay time for peak correlation increases. The ratio of spacing to peak delay time is fixed and equal to convection velocity U_C. The envelope of these correlation curves, shown as a dotted line in Figure 2, represents the autocorrelation in a frame of reference moving at U_C. The classical interpretation of this moving frame autocorrelation is that of eddies continuously deforming and giving up energy to smaller eddies through the mechanism of vortex stretching.

A different view is that the eddies themselves do not deform to any significant degree; rather, their life-

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times are randomly distributed in time [35]. The moving frame autocorrelation then indicates the probability of survival of an eddy as it convects from one probe to another. In this interpretation, the turbulence performs its work only during the time vortices are created or destroyed. The flow is relatively quiescent during the time the eddy is convecting. Since the lifetimes of the eddies vary in both space and time, the measured space-time correlation gives the impression of a continuous energy exchange. This is in agreement with other observations [6] that the Reynold stress production is highest during the period of vortex pairing, a process in which two ring-like eddies merge into a single larger eddy.

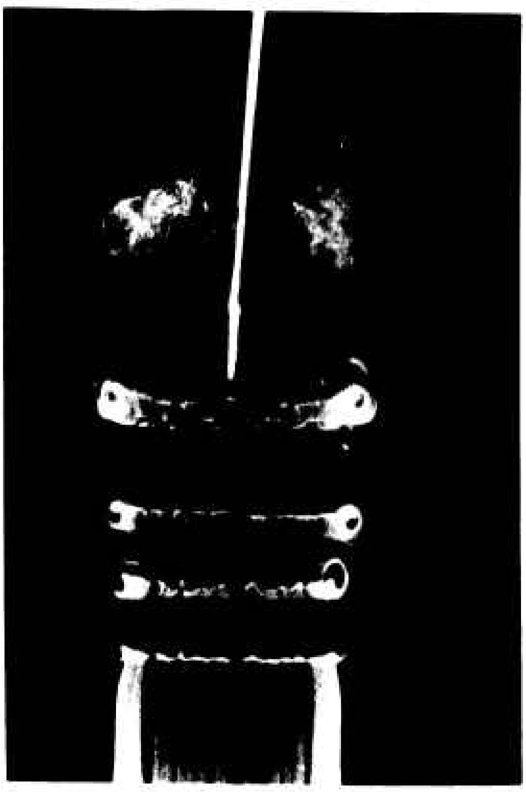

Figure 1. Ring-like Vortex Structure Made Visual in a Turbulent Jet with Smoke Injection.
R_e = 25,000; flow is from bottom to top; the long slender object is the support for the hot wire used to trigger the camera (Courtesy Professors R. Drubka and H. Nagib, Illinois Institute of Technology).

Well before coherent structures were in vogue the possibility that large eddies -- an order of magnitude larger than the energy containing eddies -- exist in shear flows was explored [16, 37]. Eddies were defined as a mean statistical quantity from space-time correlation measurements. Because these large eddies contain relatively little energy, correlation measurements would appear to say more about the energy containing scales of motion than about the largest scales. Flow visualization experiments show that the largest scales are defined more precisely than a statistical interpretation allows.

Possibly the first clue that coherent structures exist and influence noise radiation was obtained as a result of a detailed examination of the near field pressure signal [31]. It was suggested that turbulence comes in wave packets the phase of which is preserved for a few diameters as they convect downstream. The assumption is that the turbulence is convected at the phase velocity obtained from cross correlation measurements. The phase velocity is the speed that best preserves the spatial relationship between peaks and valleys of the signal; that is, an observer traveling

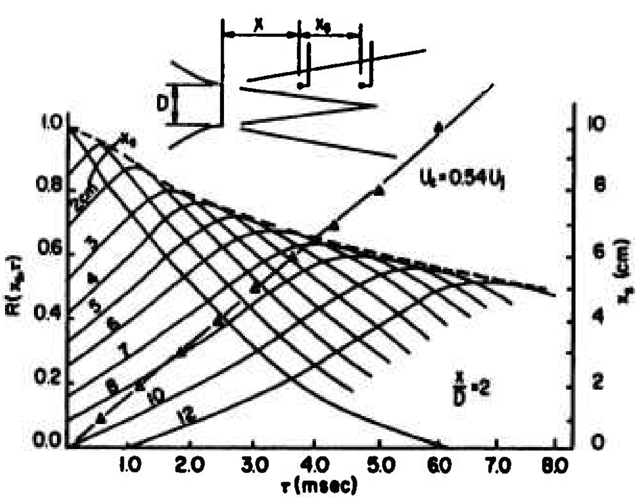

Figure 2. Typical Space-Time Correlation Data.
The straight line marked by triangles is the correlation between wire spacing x_s and the peak delay time (defined here as the tangent to the moving frame autocorrelation) [38].

at the phase velocity would see the slowest change in the signal but not necessarily the slowest change in all sizes of eddies.

Coherent structures can be considered either an orderly arrangement of well defined eddies or a large-scale, wave-like motion superimposed upon the more irregular fine grained turbulence in the flow. In fact, calculations have shown that the jet is sensitive to helical as well as axisymmetric modes [29]. This observation is interpreted in terms of vortex structure in Figure 3.

ACOUSTIC EXCITATION AS A METHOD FOR STUDYING COHERENT STRUCTURES

The lifetimes of coherent structures vary in both space and time. The introduction of small amplitude acoustic disturbances of appropriate frequency tends to bring the large scale structure into greater coherence; in effect, the wave-like motion is phase-locked to the excitation signal.

Smoke visualization has been used to determine that a naturally developing jet at a Reynolds number less than 20,000 showed little evidence of coherent structure [4]. Acoustic excitation with a loudspeaker caused readily observable axisymmetric vortices that were observed to pair into larger structures. It has been observed that similar vortical motions

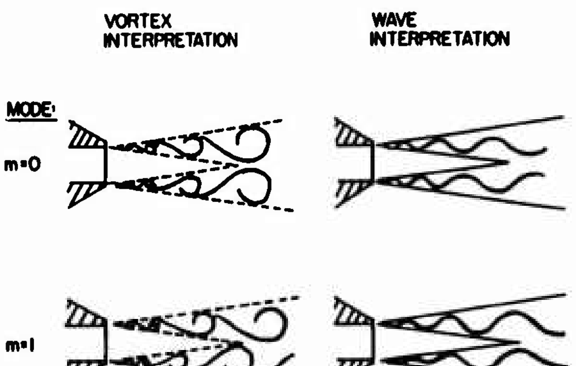

Figure 3. Alternative Viewpoints of Coherent Structure

occurred at lower Reynolds number (3000) without excitation, but distinct vortex structures at higher Reynolds number were not seen [2].

In a landmark paper Crow and Champagne [11] found evidence that the same type of orderly structure exists in a high Reynolds number jet as was previously observed in low Reynolds number jets. Coherent structures were enhanced by acoustic excitation at forcing frequencies comparable to those at which the bulk of the turbulent energy is found

$$\left(\frac{fd}{U_j} \simeq 0.3 \right).$$

Acoustical excitation results in a wave-like structure that dominates the turbulent field over the first five to six diameters of the flow at the expense of fine grained turbulence.

It has been suggested [20] that the initial shear layer instability (sensitive to much higher frequencies) can be coupled to the column mode instability studied by Crow and Champagne [11] through the mechanism of vortex pairing. The initial shear layer of a jet was excited at the most highly amplified frequency f_e (in this particular case $f_e d/U_j = 3.54$). This excitation enhanced and stabilized large axisymmetric eddies that were observed to pair at discrete positions in the jet. The vortex pairing sequence produced frequencies $f_e/2$, $f_e/4$, and $f_e/8$ in the flow field. Maximum coupling occurs when

$$\frac{f_e}{8} = f_c \text{ or } \frac{f_e}{2^n} = f_c \qquad n = \text{an integer}$$

where f_c is the column mode frequency. This is illustrated in Figure 4, which is based on unpublished work at the University of Minnesota. The dotted line is a plot of $8f_c$ vs velocity as measured in a 7.1 mm jet. Superimposed on this plot are the calculated most unstable frequency in the laminar shear layer for both an axisymmetric disturbance f_o as well as a spiral disturbance f_1 (amplification rates at the given unstable frequency are about equal).* Excitation in this case is at a constant frequency of 40 KHz. The velocity is varied such that either the helical mode or the axisymmetric mode is dominant. Typical far field noise spectra are shown in Figure 5. At M = 0.21 the axisymmetric mode is dominant; the noise spectrum contains tones at $f_e = f_o$ and its subharmonics as well as such nonlinear interaction tones as $f_o/8 + (f_1 - f_o)$ and $f_o/4 + (f_1 - f_o)$. At the

*These frequencies scale with momentum thickness, which in a laminar shear layer scale with $U^{-1/2}$ power; hence $f_u \sim U^{3/2}$.

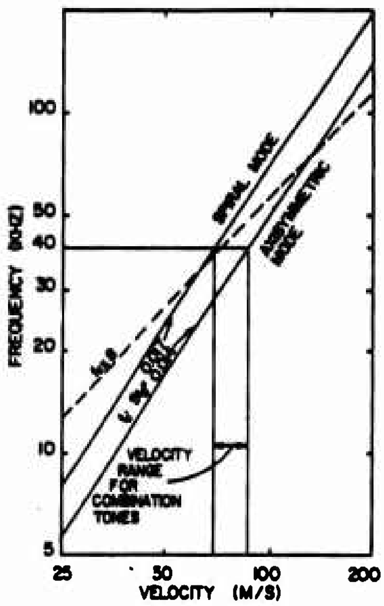

Figure 4. Frequency-Velocity Relationship for Column Mode Instability

slightly lower Mach number of M = 0.20 the helical mode is dominant; jet noise is suppressed by approximately 8dB. Comparable results have been observed [40] in the potential core.

Kibens work [19, 20] and the unpublished work at the University of Minnesota dealt with jets at relatively low Reynolds number ($Ud/\nu < 5 \times 10^4$). Recent work [27] as well as earlier work [39] indicate that jet noise at low Reynolds numbers ($<10^5$) is relatively less intense than jet noise at high Reynolds number and that differences also occur in the spectral characteristics. It is possible that the coherent structure in a jet plays a more passive role at higher Reynolds number. Significant increase was found in the broadband level of jets at high Reynolds number ($>10^5$) when forced at frequencies comparable to the column mode instability [3, 32]. In a review of aeroacoustics Crighton [10] showed that excitation at Reynolds numbers in excess of 10^5 results in increased broadband noise and conversely excitation at Reynolds numbers below 10^5

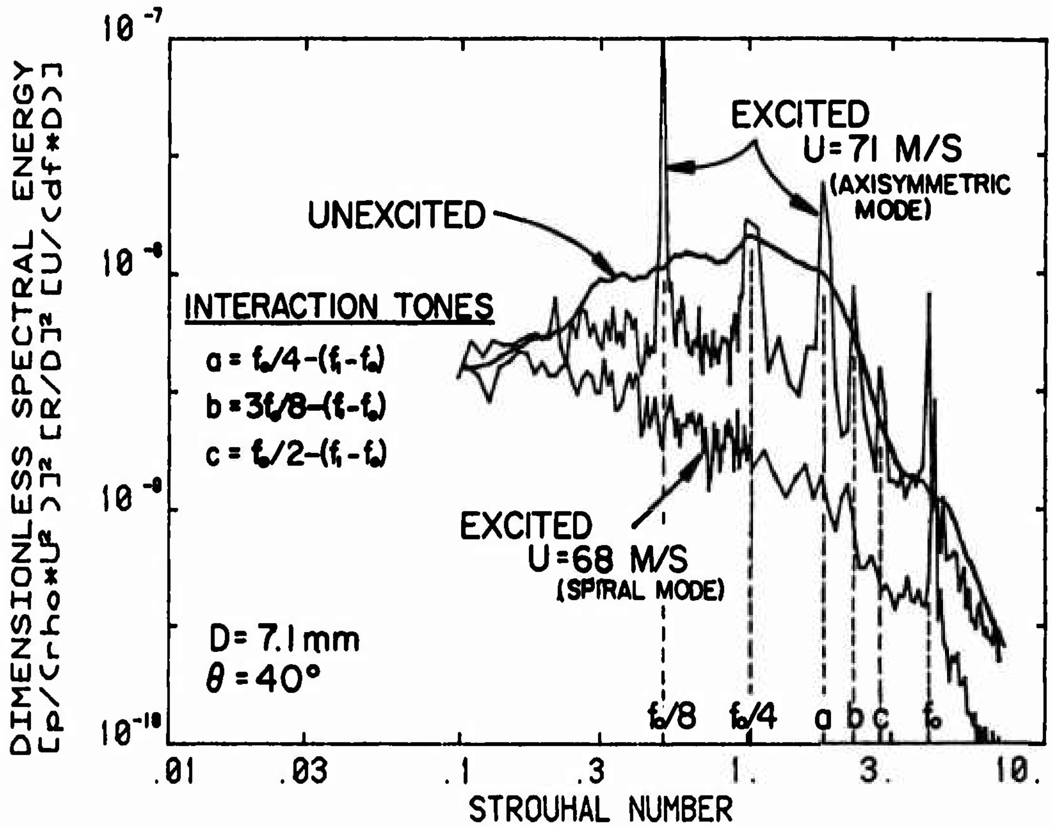

Figure 5. Comparison of Far Field Spectra from a 7.1 mm Jet.
1). natural development; 2). excitation of axisymmetric mode; 3). excitation of spiral mode

results in decreased broadband levels (albeit there can be dominant pure tones in the signal). Another important point is that noise spectra are independent of flow speed; i.e., Helmholtz number fd/a_o is a better frequency scaling parameter. This is also true for unforced jets at low Reynolds number [27].

THEORETICAL MODELS

Attempts have been made to calculate the noise radiation from coherent structure using the Lighthill theory [23, 24]. The first models proposed were discrete vortex models. Hardin [17] modeled the jet as an axial array of axisymmetric ring-like vortices convecting downstream. The analysis showed that the primary noise source mechanism is the temporal change in the toroidal radii. Other investigators [25] also used ring-like structures to model the near field pressure and found qualitative agreement between model and experiment.

Two other models, a wave model and a vortex pairing model, have been described by which noise could be produced by a large structure [12]. The wave model is based upon instability waves [26]. The noise source is seen to be the growth and decay of this wave in the axial direction. If the randomness in phase is small, the radiated noise would be narrow band. If the randomness in phase is not small even though the forcing frequency (or passing frequency) is pure tone, the radiated noise would be broadband. Experiments [32] suggest that this model is correct. The vortex pairing model is based on the possibility that the forcing term in the Lighthill model is significant only during a vortex pairing event. This conjecture has been supported by observations [6]. Another model [12] is valid only for jets in which the pairing process has a fairly regular pattern, as is the case in a forced jet or in jets at low Reynolds number. The model predicts extremely well the overall sound pressure level [32]; this is probably coincidence due to the crude nature of the model.

A triple decomposition scheme has been used to formulate the problem as an organized wave [15]. Numerical results indicate that the wave-induced stress gradients

$$\tilde{r}_{ij} \frac{\partial u_i}{\partial x_j}$$

are the significant factors in noise production. This term has been used to describe the interaction between the organized wave and the fine grained turbulence [33]. The noise is not produced by the large structure or the turbulence acting separately but by the interaction of the two. Gatski [15] also claimed that the model is supported by Moore's experimental results.

Michalke [28, 30] viewed this problem in an abstract way; he formulated coherence as a statistical quantity and not as an observable coherent structure. He used cylindrical coordinates to express the pressure terms as a Fouier series of aximuthal components of the source. He looked at single frequency components and concluded that the lowest order modes (m = 0, 1, 2) would be the most efficient radiators of sound.

An energy integral method was used to estimate the development of the lowest order modes [9]; modes beyond $m = 2$ were insignificant in terms of source coherence. Experimental results [1, 9, 13, 39] support this estimate in both the near and far fields. Recently it has been shown [5] that far field measurements of source coherence can be misleading. It can be shown theoretically [34] that an azimuthally coherent radiation pattern can be generated from a cylindrical array of incoherent sources at low Helmholtz number ($d/\lambda \ll 1$). The peak of the noise spectrum for low Reynolds number jets is at a Helmholtz number of 0.1 [27].

SUMMARY

Coherent structures in turbulent jets have been observed in naturally developing jets, especially at low Reynolds number. Detailed study requires either acoustic excitation to bring the coherent portion of the turbulent motion into greater prominence or the use of conditional sampling techniques. Flow visualization is an important experimental technique.

Theoretical models have been constructed to determine the relevance of these structures to the jet noise problem. These modes fall into four main categories: discrete vortices, instability waves, vortex pairing, and large scale-small scale interaction. The instability wave model has received the most attention. The mathematical development from first principles is straightforward, but the details are complicated.

The last two models are more complex theoretically. The vortex pairing model is really a subset of the interaction model because vortex pairing can be considered as the interaction of two large structures. When the pairing process is isolated, there is theoretical and experimental evidence that pairing produces a sufficiently violent turbulent field to account for the observed noise. When this model is extended to vortex interactions from all different sizes, the broadband noise spectrum is obtained.

It is also possible that large structures merely modulate the noise produced by more conventional turbulent sources but play no active role in the production itself. This idea is feasible but has not received sufficient mathematical treatment as yet. In fact, the evidence to date

- at low Reynolds number the noise field is somewhat less energetic
- the spectrum at all angles scales best with Helmholtz number
- forced jets produce a radiation pattern that scales with Helmholtz number
- broadband noise is suppressed by acoustic excitation at low Reynolds number and enhanced at high Reynolds number

points to a pattern. Perhaps at sufficiently low Reynolds number direct acoustic radiation from vortex pairing events can be a dominant noise source that is enhanced if the coherent structure is made dominant by acoustic excitation. At sufficiently high Reynolds number, noise due to the interaction of the wave-like structure with incoherent fine-scale turbulence might be dominant. Acoustic excitation enhances the wave-like structure; but at the same time the interaction noise is enhanced, resulting in a higher broadband level.

A summary of the significant observations on the nature of coherent structure and the supporting theoretical developments is presented in the Table.

Table. Summary of Experimental Observed Characteristics and Their Theoretical Foundation

OBSERVATION	METHOD	SUPPORTED BY	MODEL, SUPPORT
Broadband increase in radiated noise with excitation	Plenum excitation	Bechert and Pfizenmaier [3] Moore [32] Schmidt [36]	Wave model of Ffowcs Williams and Kempton [12]
Broadband decrease in radiated noise	Shear layer excitation	Kibens [20]	Pairing model
Significant Reynolds stress production during vortex pairing	Conditional sampling	Browand and Weidman [6]	Pairing model
Normalized acoustic power output is less below $Re=10^5$	Low Reynolds number and excitation	Long et al [27] Yamamoto [39]	?
Helmholtz scaling works better in the presence of large structures than Strouhal scaling	Low Re and excitation	Long et al [27] Moore [32]	?
Noise amplitude independent of excitation amplitude	Excitation	Moore [32]	Modifying effect of large structure
A spike in $\ddot{u}$ signal is correlated with a spike in far field pressure	Conditional sampling	Juve et al [18]	Vortex interaction (pairing)
Similarity between turbulence spectra and far field spectra		Fuchs [13] Fuchs and Michel [14]	Extended source wave model
Possibility of feedback of noise on initial shear layer		Laufer and Monkewitz [22] Kibens [19]	?

The important point is that not one unified theory can explain all of the experimentally observed characteristics of coherent structures. This implies that future mathematical models will require an even greater degree of sophistication.

The prognosis for future developments in this area is both bleak and bright. There is no evidence that favorable control of jet noise can occur at high Reynolds number; in fact, the problem of excess noise in jet engines becomes more insidious because noise sources within the jet engine can reorganize the turbulence in the jet in a manner that is more effective for noise generation. On the other hand, the fact that axisymmetric and spiral modes are equally sensitive within the jet and that the spiral modes appear less effective as a radiator of sound is a bright spot. In any event, the study of coherent structures has led to a new and meaningful understanding of turbulence in general. This is perhaps the most important result of this concerted effort.

ACKNOWLEDGEMENT

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LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains articles about behavior of elastomeric materials under dynamic loads and research on dynamics of composite and sandwich plates.

Mr. E.C. Hobaica of General Dynamics, Groton, Connecticut reviews literature published since 1979 on the behavior of rubber materials under small amplitude, sinusoidal forces.

Dr. C.W. Bert of the School of Aerospace, Mechanical and Nuclear Engineering, University of Oklahoma presents a survey of the literature concerning dynamics of plate-type structural elements of either composite material or sandwich construction. Papers from mid-1979 through early 1982 are reviewed.

BEHAVIOR OF ELASTOMERIC MATERIALS UNDER DYNAMIC LOADS - III

E.C. Hobaica*

Abstract. *This is a review of literature published since 1979 on the behavior of rubber materials under small amplitude, sinusoidal forces. Advances in the field in the past three years were most significant when applied to the field of damping.*

This is the third review of the state of the art of rubber when it is subjected to small amplitude sinusoidal stresses. The two previous reviews were presented in 1976 [1] and 1979 [2]. The following compilation brings the reader up to date on publications since 1979.

GENERAL

No new significant test apparatus or method of testing has appeared in the past three years. Data on dynamic properties of rubber-like materials continue to be presented in many forms. Applications of improved analysis techniques with rubber-like materials reflect a greater understanding of materials behavior, possibly due to increased cooperation between the materials engineer and the analyst. Constitutive equations are being developed that allow unified modeling of viscoelastic behavior. Correlation between molecular structure and dynamic properties remains murky and subject to limited studies at a few schools. Correlation is a field for fruitful research, particularly in the area of copolymers. It also presents the greatest potential for rapid advances in materials that push the present limits of modulus and damping.

A few articles published in the past three years fall into the category of general reviews of the subject. Perhaps of most interest is that of Snowden [3] on vibration isolation; included are an extensive discussion of static and dynamic properties of rubber-like materials and a lengthy bibliography. The article is recommended as a basic text on the use of rubber-like materials in vibration isolation and for the beginner interested in viscoelastic behavior.

Another recent summary on parameters affecting dynamic properties of elastomers [4] reviews the effects of frequency, strain amplitude, temperature, and static load including hydrostatic pressure. The interdependence of these parameters is discussed. The paper is a survey of existing literature rather than a presentation of any detailed study and is much more limited in scope than Snowden's paper.

Some of the most significant advances in the understanding of viscoelastic behavior of elastomers have occurred in conjunction with the development of damping materials. Three papers provide excellent background information on the behavior of elastomers as they function as viscoelastic dampers [5-7]. The paper by Rogers [5] is of most general interest. He presents a unified model of viscoelastic behavior under sinusoidal, relaxation, creep, and constant strain rate conditions. He has used polymer dynamics, solid mechanics, system dynamics, structural analysis, and feedback control systems to construct a unified constitutive equation.

Another attempt at a constitutive equation for an elastomer has been made [6]. A generalized model was derived and used to describe the linear frequency-dependent stiffness and damping of a particular elastomer. A constitutive relation was found that was continuous and bounded for sinusoidal strain. In the third paper [7] a modal strain energy approach was implemented with finite element techniques and used to predict modal damping loss factors of viscoelastic damped structures.

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TESTING

A number of papers have been devoted to testing methods of viscoelastic materials. Several novel and unusual techniques were described at the April, 1980 meeting of the Acoustical Society of America. The session on measurement of dynamic modulus and loss factors of viscoelastic materials covered a wide range of unusual techniques for determining the dynamic properties of elastomers [8].

The torsion pendulum continues to be a popular instrument for researchers desiring to characterize thermal transitions and mechanical relaxation processes in rubbers. Instrument data have been recorded graphically using a computer [9].

Most of the dynamic data reported in the literature are taken on rubbers at very low strains; linear viscoelastic response at such low strains can be assumed. A method for measuring dynamic viscoelastic response at large strain magnitudes has been described [10]. It was demonstrated on a series of elastomers with various carbon black loadings. The operation of the Rheovibron in the shear mode has also been described [11].

Interesting and productive work on development of data at high frequency with elastomers is going on at the Naval Surface Weapons Center. The equipment used has been described [12], and much of the dynamic data has been summarized [13]. A progressive wave technique was used in which a pulse was initiated at one end of a string of rubber. The phase and amplitude of the compressional wave were measured at several positions. The data were processed in a minicomputer; Youngs modulus and a loss factor were automatically plotted vs frequency. A wide range of frequencies (100 Hz to 20K Hz) is swept automatically, and much data are accumulated before the position of the pickup is changed.

Another article on damping materials is useful for the reader interested in testing of viscoelastic materials [14]. A very simple test was used to determine modulus and loss factors of elastomers: the transient response of a damped single-degree-of-freedom system, including the viscoelastic material, was observed and analyzed. The decaying free vibration of a simple cylindrical specimen impacted by a small hammer was measured. The response trace was recorded on a storage oscilloscope, and the amplitude ratio of successive maxima of response could be measured. Values for modulus and loss factor vs reduced frequency at different temperatures can be determined. Data by this method on two different materials compared favorably with other more complex test methods.

DYNAMIC DATA

A number of papers present some data on dynamic properties of elastomers. It is difficult to apply these data to the solution of specific material selection problems because of their diversity. The influence of carbon black loading on the dynamic properties of elastomers subjected to static deformations was investigated [15].

Dynamic stiffness and damping data were given for polyurethane foams used for sound enclosures [16]. Such materials are rarely tested in this mode. The paper would be useful in determinations of resonant frequencies and responses of structures containing such materials. The frequency band of concern was 200 Hz to 1000 Hz.

The dynamic viscoelastic response of various blends of natural rubber with two tackifier resins were evaluated on the Weissenberg rheogoniometer [17]. Two interesting presentations [18, 19] highlight the dynamic properties of various polyurethanes when used alone or blended with fillers and epoxy resin. Of particular interest were the broadening effects on loss factor of polyurethane-epoxy blends.

Much of the data generated at the Naval Weapons Systems Center on the progressive wave apparatus has been summarized [13]. The paper also includes data generated at David Taylor Naval Ship Research and Development Center in Annapolis. Dynamic data were presented over broad temperature and frequency bands.

Various blends of rubbers and plastics were evaluated on the torsion pendulum; correlations were established between blend stiffness and properties of individual components [20]. The dynamic properties of glass bead filled thermoplastic polyurethane have been measured using the rheovibron and torsion pendulum [21]. Dynamic data on four elastomers --

Viton, Vamac, neoprene, and butyl -- have been presented [22]. The Rheovibron and an inertial mass test method were used to obtain data at various temperatures. An equation for predicting the temperature sensitivity of the elastic modulus is presented.

Some dynamic data on EPDM rubbers have been presented [23, 24]. The effects of oil type, carbon black level, and a cure system for an EPDM rubber were studied [23]; six commercial EPDM rubbers were tested on the rheovibron [24].

APPLICATIONS

Recent work on elastomeric bearings is important because it illustrates design parameters and typical bearing applications of elastomeric materials. Data on dynamic properties of elastomer cartridges operating under a rotating load were presented [25]. The dynamic properties of two elastomer buttons and a shear specimen were tested on a resonant mass apparatus, and temperature distribution was measured. The experimental results were compared with analytical productions. Data on dynamic properties of elastomer cartridges operating under a rotating load were given [26]. An elastomer damper was compared to a hydraulic damper for a power transmission shaft [27], and a guide for the design of elastomeric dampers in rotating machinery was presented [28].

Two articles are of peripheral interest in this review in that they describe two bearing applications for natural rubber [29, 30]. The first covers bearings for large structures and contains relevant static and dynamic properties of natural rubber and some mathematical modeling of rubber behavior. The second covers rubber bearings in transport and is primarily application oriented.

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RESEARCH ON DYNAMICS OF COMPOSITE AND SANDWICH PLATES, 1979-81

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Abstract. This paper presents a survey of the literature concerning dynamics of plate-type structural elements of either composite material or sandwich construction. Papers from mid-1979 through early 1982 are reviewed. Particular attention is given to experimental research and to linear and nonlinear analysis. Configurations include rectangularly orthotropic, cylindrically orthotropic, and anisotropic plates; laminated plates; and thick and sandwich plates. Free and forced vibration, flutter, and impact are considered.

The fundamentals of the mechanics of composite and laminated plates have been discussed in a previous two-part survey [1], which was updated in 1979 [2]. Other recent surveys that are closely related to the present work include the author's survey of vibration of composite structures [3], a survey by Leissa on complicating effects in free vibration of plates [4], another paper by the same author on vibration, buckling, and postbuckling of composite plates [5], and a survey by Reddy on finite-element analyses of composite plates and shells [6].

Information sources referenced in this survey are primarily papers in the open literature and a few reports. The following topics are not included: anisotropic-crystal plates, magnetoelastic effects, and plates with cracks.

EXPERIMENTAL RESEARCH

Research that is primarily experimental rather than analytical is described in this section. It is encouraging to note an increase in experimental research since the 1970 survey [2].

Sinusoidal and random loadings. Crawley [7] investigated the resonant frequencies and mode shapes of a series of clamped rectangular plates and cylindrically curved panels. The plates were of graphite/epoxy and hybrid graphite/epoxy/aluminum alloy and were laminated in various symmetric lamination schemes. The experimental results were compared with those of a mixed finite element developed by Lee and Pian [8]. Agreement for mode shape was excellent. Agreement for frequencies was reasonable; discrepancies were attributed to differences between dynamic flexural and static in-plane moduli.

Rasskasov and Sokolovskaya [9] investigated the static and frequency response of a series of hinged and combined-support rectangular plates of single-core and double-core sandwich construction. They included four lamination schemes symmetric with respect to the midplane and four unsymmetric schemes. The stiff layers were of sheet steel and of glass/polymer; the cores were of foam plastic. The results were compared with analytical results for hinged supports.

Teh and White [10] conducted experiments on eight-layer graphite/epoxy (and aluminum-alloy) panels with clamped edges. The panels were subjected to a combination of uniaxial compression and random acoustic pressure loading to simulate conditions representative of an aircraft flight environment. Experimentally determined frequencies were generally lower than those obtained by Rayleigh-Ritz theoretical analysis.

Chamis and his associates [11] reported on an innovative series of experiments to determine the resonant frequencies and damping factors of laminated panels previously subjected to damage induced by residual stresses and monotonic or cyclic applied loads. The materials were glass/epoxy and high-modulus-graphite/epoxy in various lamination schemes. They concluded that the dynamic response of the

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glass/epoxy panels was susceptible to low-level damage, but that the response of the graphite/epoxy ones was not.

Impact and blast loading. The considerable recent experimental research on impact loading of composite plates has been surveyed recently by Takeda and Sierakowski [12]. An extensive series of experiments reported by Takeda, Sierakowski, and their associates [13-16] were concerned with glass/epoxy laminated panels subjected to local ballistic impact. Emphasis was on the delamination failure mechanisms.

Rhodes and his associates [17] investigated low-velocity impact damage in graphite/epoxy panels; Hayes and Rybicki [18] reported on experiments on panels of graphite/epoxy, aramid/epoxy, and their hybrids. They also concentrated on delamination failure. Knauss [19] reported on the use of the moire fringe technique to determine the phenomenological aspects of damage due to low-velocity impact in graphite/epoxy laminates.

In a series of experiments C.T. Sun of Purdue University and his associates [20-22] focused attention on the contact law and its role in the dynamic response of locally impacted plates.

Rajamani and Prabhakaran [23] investigated the response of unidirectional glass-epoxy plates subjected to blast loading produced by a shock tube. Both solid plates and plates with a central circular hole were studied. The measured dynamic amplification factors for glass/epoxy averaged about 35% lower than those for homogeneous aluminum-alloy plates.

LINEAR ANALYSES OF THIN PLATES

Linear analyses of thin plates assume linear stress-strain behavior of the material and small deflections so that strain-displacement relations are linear. Furthermore, in many cases the material is assumed to be macroscopically homogeneous through the thickness. Thus, the material can consist of either a single layer of composite material or multiple layers provided that all layers have the same orientation. Three categories of reinforcement geometry are considered in this section: specially orthotropic and generally orthotropic (equivalent to anisotropic) with respect to rectilinear coordinates and cylindrically orthotropic (such as approximated by manufacture using the filament-winding process). Thin laminates (nonhomogeneous through the thickness) are also discussed.

Specially orthotropic thin plates. Specially orthotropic thin plates have the principal-material-symmetry axis oriented parallel to a geometric axis of the plate (such as a center line or axis of symmetry). Sakata [24, 25] reviewed the use of reduction methods to convert numerical results for isotropic plates to those for specially orthotropic plates.

In a series of papers Laura and his associates [26-31] used polynomial approximating functions in conjunction with either the Rayleigh-Ritz or the Galerkin method. Part of the work [26-28] was concerned with rectangular plates having elastically restrained edges. Various combinations of free and elastic edges were analyzed [26], as were an attached concentrated mass [27] and plates tapered in two directions [28]. The solid circular planform was considered [29], as were the polygonal planform [30] and a methodology for analysis of either clamped or simply supported planform with numerical results only for regular polygons [31].

A number of other analyses were concerned with rectangular-planform plates. For example, Wilson [32] considered an infinite plate strip on an elastic foundation and subjected to line loads and moments traveling at constant speed. It is cautioned that in this analysis, an incorrect equivalent isotropic plate approach is used. For example, the Poisson-bending and twisting term

$$2(D_{12} + 2D_{66}) \frac{\partial^4 w}{\partial x^2 \partial y^2}$$

is replaced by the following much more restrictive term:

$$2(D_{11}D_{22})^{\frac{1}{2}} \frac{\partial^4 w}{\partial x^2 \partial y^2}$$

D_{11} and D_{22} are the flexural rigidities in the x and y directions, D_{12} is the Poisson-bending rigidity, D_{66} is the twisting rigidity, w is the plate deflection, and x and y are the longitudinal and transverse directions in the plane of the plate.

Sakata [33] treated simply supported rectangular plates with stepped thicknesses, using the reduction method [24, 25]. Ganesan and Dhotarad [34] analyzed plates tapered in one direction with temperature-dependent elastic properties and subjected to a temperature gradient. They used the finite-difference method to consider all edges clamped, all edges simply supported, and opposite edges clamped and simply supported. Sobotka [35] analyzed viscoelastic plates with the latter two combinations of boundary conditions. However, this analysis has been severely criticized [36].

Kuttler and Siglillito [37] applied to clamped rectangular plates their method [38] for obtaining upper and lower bounds on the natural frequencies. Bucco et al [39] applied a combination of the finite-strip method [40] and the deflection-contour method [41] to various shapes of isotropic plates and to clamped, square, orthotropic plates. Narita [42] used a series method to attack the problem of free vibration of a plate that is partially restrained along portions of its edges and simply supported on the remainder.

Simply supported plates of parallelogram planform were considered by Sakata [43] using the reduction method [24, 25]. Forced vibration of polygonal plates with linear damping was analyzed by Katsaitis [44]. Plates of infinite planform extent were considered by Busch-Vishniac [45], who derived the driving-point impedance in the presence of initial tension, and by Das and Roy [46], who considered arbitrary forcing functions for plates on elastic foundations.

Anisotropic (generally orthotropic) thin plates. In a series of paper [47-49], Laura and his associates considered plates of rectangular planform, using polynomial approximating functions and either the Rayleigh-Ritz or the Galerkin method. Elastically restrained edges were treated [47]; clamped edges and in-plane initial loads were included [48]. The effect of a small, free-edge diagonal cutout at a corner was also investigated [49].

Sakata and Hayashi [50] conducted both analytical (using the reduction method) and experimental investigations of parallelogram plates.

Irie and Yamada [51] used the Rayleigh-Ritz method in conjunction with spline functions to analyze elliptic plates with confocal elliptic holes. Although the equations were developed for general orthotropy, they were implemented numerically only for special orthotropy.

Polar (cylindrically) orthotropic thin plates. Cylindrically orthotropic (or polar orthotropic) plates are those with directions of material symmetry that coincide with a circular cylindrical coordinate system. In practice, such plates are made by winding filaments circumferentially on a circular mandrel. In a plate (or disk) configuration, the plates are most widely used as reinforcements at circular cutouts or as rotating disks (energy-storage flywheels and turbine or compressor disks). Biaxial loadings are present in both of these categories of application and the most efficient designs involve varying thickness (radial taper). Surprisingly, during the time interval covered in this survey, apparently only one paper on vibration of a varying thickness plate subjected to inplane preload appeared. This was the work of Dyka and Carney [52]. They considered a circular annular plate with parabolic thickness variation and ring-type stiffeners at both edges and subjected to uniform radial compressive load at the outer edge.

Circular plates subjected to centrifugal preload were considered by several investigators. The in-plane torsional vibrations of both radially tapered and uniform-thickness disks were analyzed by Ochan [53], who developed expressions for the critical speed of rotation for dynamic instability. Flexural vibration of a uniform-thickness plate with ring-type stiffeners at both edges was treated by Dyka and Carney [54]. Laura et al [55] made Rayleigh-Ritz and FEM (finite-element method) analyses of uniform plates subjected to uniform in-plane prestress.

Flexural vibrations of varying thickness plates without preload were studied by several investigators. Lenox and Conway [56] presented a closed-form solution for vibration of a plate with a parabolic thickness variation vibrating in any arbitrary combination of radial and circumferential nodes. This solution should be valuable in assessing the accuracy of various approximate numerical techniques. Bell and Kirkhope [57] considered plates with piecewise stepped radial thickness variation by extending the isotropic transfer-matrix analysis due to Ehrich [58].

Both FEM analysis and experiments were used by Ginesu et al [59] to study flexural vibrations of uniform-thickness plates with various boundary conditions. Gorman [60] used an FEM analysis [59] to develop extensive tabular results for uniform-thickness annular plates with various combinations of clamped, free, and simply supported edge conditions. Avalos and Laura [61] used a Galerkin polynomial approach to treat the axisymmetric flexural modes of annular plates with elastic rotational restraints. Tani [62] investigated the dynamic instability of annular plates subjected to pulsating torsion in their plane.

Sector plates have a quadrilateral planform in the shape of a sector of an annular circular plate. The Rayleigh-Ritz method was used to analyze free vibrations of such plates. Irie et al [63] used spline functions as the admissible function; Ramaiah [64] used simple polynomials.

Laminated thin plates. In the time frame covered in this survey, there have been relatively few linear analyses of laminated thin plates. C.T. Sun of the University of Florida presented an excellent tutorial exposition [65]. Crawley and Dujundji [66] made a Kantorovich variational analysis of symmetrically laminated cantilever plates. Lin [67] considered clamped, free, and simply supported plates resting on a viscoelastic foundation and subjected to a constant force moving along the plate at constant speed.

Stavsky and his associates [68, 69] considered the arbitrary-mode vibration of circular plates consisting of concentric cylindrically orthotropic layers. Two different eigenvalue solution schemes were used: a classical approach [68] and a finite-difference scheme [69]. In these works it was shown that certain lamination schemes are capable of producing higher fundamental frequencies that can be attained by homogeneous plates of either constituent material. This is not surprising, as it is the basis for the use of sandwich construction.

Dynamic fracture mechanics of a laminated plate were considered [70]. Laminated composite plates (cross-ply laminates and isotropic-material laminates) with discrete stiffeners were analyzed by Chao and Lee [71] using a classical approach.

Although the potential for tailoring of laminates is usually mentioned as one of their advantages, most optimization to date has been on an ad hoc basis and has not considered dynamic criteria (objective functions or constraints). Rao and Singh [72] attempted to remedy this situation in a recent formal optimization using nonlinear mathematical programming. They considered minimum-weight design with constraints on minimum fundamental natural frequency, minimum buckling load, and maximum static deflection.

LINEAR ANALYSES OF MODERATELY THICK PLATES

Due to the low thickness shear moduli of fiber-reinforced composite materials relative to their flexural elastic moduli, it is advisable to include thickness shear deformations (sometimes called transverse shear deformations) in dynamic analyses of plates made of such materials. This inclusion is often necessary even in the case of plates having geometrical parameters such that they would be considered thin if they were constructed of homogeneous isotropic material. Inclusion of thickness shear deformations has resulted in the generation of the analyses that are discussed below. Because there is considerable analogy between so-called sandwich plates and homogeneous or laminated plates with thickness shear deformation included, sandwich plates are also discussed.

Specially orthotropic, generally orthotropic, and cylindrically orthotropic plates with thickness shear flexibility. A new and improved theory includes thickness stretching as well as thickness shearing deformation [73]. The theory was applied in a Ritz-Galerkin analysis of a cantilever, rectangular plate of CFRP (carbon-fiber reinforced plastic) and hybrid glass FRP and CFRP plates.

Dobyns [74] presented a simplified analysis of simply supported plates subjected to blast loading. He called his materials laminates but neglected bending-stretching coupling (B_{ij}) and bending-twisting coupling (D_{16} and D_{26}). The symbols are classical laminated plate theory notation [75, 76]. An orthotropic high-precision finite element [78] was extended [77] by adding the effects of an elastic foundation.

Patra and Iyengar [79] made a displacement-function FEM analysis of a generally orthotropic rectangular plate clamped at its outer edges and containing a free-edge circular or rectangular cutout.

Cheung and Chan [80] applied the finite-strip method [40] to cylindrically orthotropic sectorial plates. Other work has also been reported [63, 64].

Laminated plates with thickness shear flexibility. In a recent monograph, Bolotin and Novichkov [81] covered such aspects of the mechanics of laminates as vibration and wave propagation of laminated plates including thickness shear deformation. Green and Naghdi [82] developed a new dynamic thermoelastic theory of plates laminated of orthotropic materials and applied it to analysis of propagation of harmonic waves in three-layer plates.

Khoroshun [83] also developed a new theory of laminated plates and shells. It differs from the classical Reissner-Mindlin type theories (and Timoshenko beam theory) in that it does not require ad hoc determination of the shear correction factors. In this respect it is analogous to the new theory of homogeneous plates introduced by Levinson [84]. Khoroshun and Ivanov [85] applied Khoroshun's new theory to wave propagation in two-layer laminated plates.

Chatterjee and Kulkarni [86] developed a dynamic approach to determination of the shear correction factors for the Whitney-Pagano shear-deformable laminate theory [87]. The factors were obtained by matching cutoff frequencies for propagation of thickness shear waves predicted by plate and elasticity theories. In general slightly lower values than those predicted by Whitney [88] using a static approach are obtained. Chatterjee and Kulkarni [89] made an extensive investigation of the effects of material damping, temperature, and moisture on the panel flutter of graphite/epoxy laminates.

The moving-load response of a two-layer plate on a compressible fluid half-space was investigated by Chonan [90]. A similar configuration was studied by Crighton [91].

Reddy [92] used his isoparametric finite element to analyze free vibration of simply supported rectangular plates of angle-ply lamination scheme. He gave numerical results showing the effects of plate aspect ratio, relative thickness, and lamination angle on plates of two different materials typical of high-modulus graphite/epoxy and high-strength graphite/epoxy. Reddy and Chao [93] studied the effect of reduced integration, mesh size, and element type (linear or quadratic) on predicted natural frequencies of cross-ply and angle-ply plates.

Witt and Sobczyk [94] analyzed the cylindrical-bending response of simply supported laminated plates to random-pressure loading. Sih and Chen [95] performed a dynamic fracture mechanics analysis of a four-layer plate containing a crack and subjected to sudden stretching. In a series of three papers, Guyader and Lesueur [96-98] considered vibration modes, transmission under oblique plane-wave excitation, and transmission under reverberant sound excitation.

Wave propagation in laminated plates was recently considered by two different sets of investigators. Kim and Moon [99] used a Laplace transform in time and a Fourier transform in space and reported information on longitudinal waves, thickness waves, and wavefront surfaces. A similar analysis was made by Sun and Tan [100], who then tied it in with Sun's previous impact-law work [20-22] to predict plate response to localized impact loading.

Certain materials, including fiber-reinforced composites with soft matrices, biological tissues, and brittle materials such as concrete, have quite different stress-strain curves when loaded in compression rather than tension. As a first approximation to the stress-strain behavior of such materials, Timoshenko [101] (one dimensional case) and later Ambartsumyan [102] (general case) suggested the use of a bilinear approximation, with different moduli in tension and compression (thus called bimodular). This approach was extended to fiber-governed soft-matrix composites [103]. Recently Bert, Reddy, et al [104] presented the results of closed-form and FEM analyses for free vibration of rectangular plates cross-plied of such bimodular composite materials. More recently Reddy [105] reported on FEM analyses of such plates subjected to transient loadings.

A specialized category of laminate is a plate with unconstrained damping treatment, usually on one side of a substrate, so that the laminate has a total of two layers. The plate substrate is usually constructed of a homogeneous, isotropic material (although it could be of composite material), and the damping layer is usually a low-modulus, high-damping material such as an elastomer. Recent research into various kinds of damping treatments was surveyed by Nakra [106].

In a series of three papers, Ramachandra Reddy and his associates [107-109] analytically and experimentally investigated the response of plates with unconstrained damping layers to random acoustic excitation.

Sandwich plates. A sandwich plate is one having a lightweight, flexible, relatively thick core (or several cores) with attached, stiff, relatively thin facings. Thus, it is customary to neglect transverse shear deformation in the facings and to include all of the transverse shear deformation in the core (or cores). The geometric configuration can be either symmetric or unsymmetric with respect to the midplane of the core.

Two papers were concerned with the effects of the in-plane inertia terms. Markus and Nanasi [110] made an extensive investigation of axisymmetric free vibration modes of clamped circular plates with isotropic facings and cylindrically orthotropic core. Grover and Kapur [111] analyzed the transient response of undamped, simply supported, rectangular plates subjected to a half-sine acceleration pulse. The materials were all isotropic; however, the facings were unsymmetric with respect to the midplane of the core. It was found that, for relatively short loading durations, the effects of both rotatory and in-plane inertia actions were significant; for relatively long shock durations the effects were small.

Chonan [112] made a theoretical analysis of an infinitely long plate with thick facings and initial, in-plane, compressive stresses that was subjected to a line load moving at constant speed. The same author also analyzed both axisymmetric and unsymmetric modes of circular annular plates with initial radial tension and elastically supported at both the inner and outer edges [113]. Gupta and Jain [114] analyzed the free vibration of circular annular plates with linear radial thickness variation; they used a cubic spline method.

Two papers were concerned with plate response to random acoustic loading. Ramachandra Rao and his associates [115] made a Galerkin-type analysis of clamped square panels with isotropic elastic facings and isotropic viscoelastic core. Reasonable agreement with experimental results was obtained. Narayanan and Shanbhag analyzed the sound transmission and structural response of an ordinary isotropic sandwich panel [116] and one backed by an acoustic fluid cavity [117].

Ibrahim and his associates [118] made one of the few recent analyses of sandwich plates with facings of anisotropic material and arranged unsymmetrically (incorrectly called unbalanced) with respect to the core middle plane. They considered simply supported rectangular plates with cross-ply and angle-ply facings.

In a series of two pioneering papers, Park and Bertoni [119, 120] analyzed elastic wave propagation in a hexagonal-cell honeycomb core (not a complete sandwich). In the analysis they considered the discontinuous nature of the detailed honeycomb geometry. Thus, the waves considered were Bloch waves, which are analogous to plane waves in an elastic continuum. The purpose of their investigation was to support the use of high-frequency waves for nondestructive evaluation of honeycomb cores and panels with honeycomb cores. However, in light of the widespread use of hexagonal-cell cores in aircraft structural panels, their work should be of great interest to the structural dynamics community as well. Their results showed that the honeycomb acts as an elastic continuum only at low frequencies [119]. They also made a detailed study of the dispersive effects produced by the periodic nature of the structural configuration [120].

Torvik [121] recently reviewed the analysis and design of constrained-layer damping; i.e., a sandwich consisting of a flexible, high-damping core with thin, stiff, low-damping facings. For such structures with equally spaced discrete stiffeners, Slazak and Vaicaitis [122] developed an ingenious extension of the transfer-matrix method.

Considerable recent activity has been aimed toward the development of finite-element models of damped sandwich panels, or constrained-layer damping [123-128].

NONLINEAR ANALYSES

Although nonlinear analyses involve more computational effort than linear ones, the former are sometimes necessary, particularly in large-amplitude vibration (geometric nonlinearity), in which the slopes are sufficiently large to require the use of nonlinear strain-displacement relations; and in nonlinear constitutive equations.

Geometrically nonlinear thin plates. Although the formulation of the equations governing the fundamental kinematic behavior of thin isotropic plates in the presence of geometric nonlinearity is generally attributed to von Karman in 1910 [129], it was not brought into the formulation of laminated composites until the work of Whitney and Leissa in 1969 [130].

The most comprehensive work on the geometrically nonlinear analysis of both the static and dynamic behavior of thin plates is Chia's recent book [131]. Particularly pertinent are Chapter 1 on nonlinear theory of laminated plates and Chapters 6 and 8 on postbuckling behavior and nonlinear flexural vibration of anisotropic plates and of unsymmetrically laminated anisotropic plates.

Table 1 is a summary of recent research papers [132-142] on geometrically nonlinear vibration of thin anisotropic and/or laminated plates. It should be mentioned that a specific investigation was made [138] to illustrate the errors that can result from the use of Berger's approximation [143].

Table 1. Analysis of Large-Amplitude Vibration Thin Anisotropic and/or Laminated Plates

Investigators	Reference	Planform Geometry	Material Class*	Type of Problem	Type of Solution
Alwar & Reddy, Nath & Alwar	132, 133	Circular	CO with damping	Transient loading	Chebyshev polynomials in space; Houbolt numerical integration in time
Kanaka Raju & Venkateswara Rao	134	Circular (radially tapered thickness)	CO	Free vibration	Finite-element method
Venkateswara Rao & Kanaka Raju	135	Circular	CO	Axisymmetric free vibration	Finite-element method
Kunukkasseril & Venkatesan	136	Circular	Laminated isotropic	Axisymmetric free vibration	Galerkin
Chia & Sathyamoorthy	137	Parallelogram	RO	Free vibration	Galerkin
Prathap & Varadan	138	Parallelogram	RO	Free vibration	Galerkin
Sathyamoorthy	139	Elliptic	RO	Free vibration	Galerkin (combined deflection and stress-function formulation)
Sathyamoorthy & Chia	140	Elliptic	RO	Free vibration	Explicit polynomials (three displacement formulation)
Mei & Wentz	141	Rectangular	Laminated anisotropic w/damping	Random acoustic loading	Galerkin
Niyogi & Meyers	142	Rectangular	RO	Free vibration	Perturbation

***The symbols CO and RO denote cylindrically orthotropic and rectangularly orthotropic, respectively.**

Geometrically nonlinear plates with thickness shear flexibility. Considerable recent analytical research on plates that are geometrically nonlinear and yet have thickness shear deformation and rotatory inertia has emanated from only five research teams. The most extensive work was by Sathyamoorthy, either alone [144-149] or with Chia [150-153]. In these investigations of a variety of planform geometries the same general methodology was used throughout: Galerkin solution in conjunction with Runge-Kutta numerical integration. No laminated plates were considered, although both specially orthotropic and generally orthotropic ones were; see Table 2 for details. It is interesting that Sathyamoorthy [146-148] investigated use of the Berger hypothesis [143] and found that it did not result in more than about 5% error for the cases investigated. Wang and Wang [154] used the Galerkin method and the method of multiple scales.

The most extensive finite-element work was by Reddy and his co-workers [155-160]. They investigated a variety of material classes and both free vibration and transient loading, as can be seen in Table 3. Other work has also been reported [161, 162].

Plates with nonlinear material behavior. Due to the mathematical complexities involved, there have been very few analyses of composite panels with nonlinear material behavior. Katsaitis [163] considered the sinusoidally forced vibration of a clamped, rectangular, thin plate of specially orthotropic material having nonlinear damping. Ni [164] used a quadrilateral finite-element approach based on the finite-difference energy method to analzye thin panels constructed of materials with a cubic nonlinearity in in-plane shear deformation. Geometric nonlinearity was also included.

Table 2. Galerkin-Type Analyses of Large- Amplitude Vibration of Thick Anisotropic Plates

Investigator(s)	Reference	Planform Geometry	Material Class*	Flexural Boundary Conditions
Sathyamoorthy	144	Rectangular	RO	Simply supported
Sathyamoorthy	145, 146	Parallelogram	RO	Clamped
Sathyamoorthy	147	Circular	RO	Clamped
Sathyamoorthy	148, 149	Elliptic	RO	Clamped
Sathyamoorthy & Chia	150	Circular	RO	Clamped
Sathyamoorthy & Chia	151, 152	Parallelogram	GO	Various
Sathyamoorthy & Chia	153	Rectangular	GO	Various
Wang & Wang	154	Rectangular	RO	Clamped & simply supported

**The symbols GO and RO denote generally orthotropic and rectangularly orthotropic, respectively.*

Table 3. Finite-Element Analyses of Large-Amplitude Vibration of Thick Anisotropic and/or Laminated Plates

Investigator(s)	Reference	Planform Geometry	Material Class*	Type of Problem
Reddy, Huang, & Singh	155	Circular	CO	Free vibration (axisymmetric modes)
Reddy & Huang	156	Circular annular	CO	Free vibration
Reddy & Chao	157	Rectangular	RO	Free vibration
Reddy & Chao	158	Rectangular	LA	Free vibration
Reddy	159	Rectangular w/rectangular cutout	LA	Free vibration
Reddy	160	Rectangular	LA	Transient
Kanaka Raju et al	161	Rectangular	RO	Free vibration
Mota Soares et al	162	Rectangular	RO	Transient

**The symbols CO, RO, and LA denote cylindrically orthotropic, rectangularly orthotropic, and laminated anisotropic, respectively.*

In two reports [165, 166] Zak and Pillasch used a quadrilateral finite element to model the transient behavior of laminated plates with geometric nonlinearity and orthotropic elastic-viscoplastic material behavior. The numerical time integration was accomplished by a finite-difference technique.

TRENDS AND SUGGESTIONS FOR FUTURE RESEARCH

These trends are notable in the research reviewed here:

- Increased emphasis on experimental research
- Considerable increase in the number of analyses including thickness shear flexibility
- Continued expansion of the use of the finite-element method, especially in the analysis of nonlinear problems

The author believes that the following aspects should be investigated more fully in the future:

- Analyses of plates under transient loading
- Expanded attention to more realistic material models, including nonlinear stress-strain relations and material damping [167]
- Analyses of geometrically nonlinear panel flutter
- Interaction between vibration loading and material flaws, including fatigue crack propagation
- Study of the effects of laminate residual stresses, due to thermal-expansion mismatch, on vibration response of laminated plates
- Increased attention to material and laminate optimization, including hybrid composites

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BOOK REVIEWS

ACOUSTIC EMISSION

R.V. Williams
Heyden & Son, Ltd., Philadelphia, PA
1980; 140 pp; $29.00

Acoustic Emission is essentially an expanded literature review of the classical acoustic emission field; emphasis is on application of acoustic emission technology in the United Kingdom during the last half of the 1970s. Most of the book is devoted to a review of published literature, but Williams includes information from numerous private communications, his own observations, and a critique of classical acoustic emission applications. He has written a good introductory monograph on the subject.

The applications discussed deal almost entirely with the use of acoustic emission for detecting and locating cracks and defects and for determining crack growth in structures. Little mention is made of such closely associated technologies as microseismic activity, boiling detecting, cavitation detection, and incipient failure detection in rotating machinery. One page of the monograph contains information on detecting leaks using acoustic emission, but the author's expertise in this field seems to be limited. He often refers to this application as a new development; however, as early as 1961, a popular leak detector, manufactured by Delcon in the UK, was being marketed by Hewlett Packard in the United States. The device, which operates in the lower acoustic emission frequency band, detects leaks by the same principle as newer acoustic emission leak detection systems.

The book contains chapters on the following topics: acoustic emission techniques and systems; acoustic emission related to metallurgical effects; monitoring the welding process; and applications to pressurized systems, fiber-reinforced materials, concrete, aircraft, and offshore structures. Williams is to be commended for his candor in describing both the problems associated with these acoustic emission applications and the benefits. His remarks concerning the careful approach necessary when a new application of acoustic emission is attempted -- including the need to investigate various frequency bands in order to optimize signal-to-noise problems and the need for a skilled operator -- were particularly appreciated by this reviewer. Manufacturer sales literature usually provides sufficient information on the application of hardware, but it is often difficult to determine the problems associated with its use.

A quarter of the book is devoted to a chapter on acoustic emission techniques and systems. Williams discusses the improved correlation with crack growth obtainable from energy analysis. That energy analysis is preferred over ring-down counting or event counting of acoustic emission pulses is interesting because early acoustic emission hardware used counting techniques almost exclusively, whereas rotating machinery incipient failure detection methods relied on energy analysis. It is unfortunate that only one page in this chapter is devoted to a discussion of acoustic emission transducers in view of the controversy in the field with regard to absolute units of measurement and primary standards. However, the author does discuss various secondary calibration techniques that can be used to verify the operation of an acoustic emission system.

Treatment of the acoustic emission relationship to metallurgical effects is fairly mathematical, as is the material that is reviewed. Williams points out that the relationship between acoustic emission and crack growth has been studied by many investigators with dissimilar results. He concludes that "It is consequently dangerous to read too much into the absolute determination of counts during pressure testing, rather one should rely on defect location coupled with conventional nondestructive examination of appropriate areas."

The author's treatment of the application of acoustic emission to pressurized components covers hydrostatic tests on pressure vessels, in-service testing of pressure vessels, and surveillance of components subjected to stress-corrosion and high-pressure gas pipelines. He summarizes the results of 19 acoustic emission tests carried out on pressure vessels by various investigators and concludes that the results provide "impressive evidence of the value of this method for checking the safety of these important structures, where the consequences of failure are severe." Williams lists nine permanent installations of in-service acoustic emission surveillance systems; however, he gives no details of the results obtained with these systems or of the operational problems involved with their use. Such information would have added significantly to the value of the monograph.

Williams provides a good treatment of acoustic emission applied to the welding process. He discusses its application to spot, arc, and electron-beam welding and provides details of the problems of background noise in welding.

The chapter on offshore application of acoustic emission should be of interest to those in the offshore industry. Williams summarizes the work of Rogers and Webborn of the Unit Inspection Company and underwater test results on the viking field jacket structure, showing acoustic emission activity at a diagonal branch weld. He also describes various noise sources and ways to minimize their effects.

The minimal coverage of the acoustic emission application to aircraft structures reflects the small amount of literature that has been published in this area. Although aircraft structure testing would appear to be a natural application for acoustic emission, Williams points out that it is not yet an accepted method, mainly because of problems with background noise. The author states that work in this area is still at an early stage, but I am aware of one large aerospace company, working in acoustic emission since the mid 1960s, that dropped its acoustic emission program in the mid 1970s.

The final chapter covers the application of acoustic emission to carbon-fiber-based reinforced materials, bonded joints, and concrete. Results of testing on both ordinary Portland cement and high-alumina cement by the Fulmer Research Institute and by Acoustic Emission Consultants Ltd. in cooperation with the British Gas Corporation are summarized.

This book should prove useful as both an introductory text for new and potential users of classical acoustic emission technology and as an update for experienced users wishing to remain current in the field.

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AN INTRODUCTION TO THE DESIGN AND BEHAVIOUR OF BOLTED JOINTS

J.H. Bickford
Marcel Dekker Inc., New York, NY
1981; 443 pp; $45.00

Although joints are essential in fabricated structures, bolted joints are often the weakest element in a structure. Leaks can develop, and wear and slip can eventually lead to failure of the structure. However, despite their importance, bolted joints are not well understood because their behavior involves a large number of variables that are difficult or impossible to predict and control. This book will be welcomed, therefore, by anyone concerned with the design or performance of bolted joints because it exposes the reader to the problems relating to bolted joints and their solution.

The introduction describes stress and strain in bolts and the statistical variation of these quantities. The author next considers methods for tightening a joint to the desired bolt pre-load. Bolt torque control is shown to be a versatile and easy method for setting a desired bolt pre-load, but limitations allow a ± 25-30% variation in pre-load. Bolt turn measurements also vary. Consideration of turn and torque together is shown to be a more accurate method for setting pre-load, and several devices for measuring the two are mentioned. However, the stretch in bolts is a far more accurate method for determining pre-load; ultrasonic methods are described. Bolts and load washers equipped with strain gauges can also be used to determine bolt stretch. The author emphasizes that, at present, there is no practical way to measure bolt stress or tension accurately.

Loads on bolted joints in service are considered to comprise tensile loads, shear loads, working loads, shear plus tension loads, eccentric loads, and loads from prying actions. Nonlinear joint behavior and relaxation are also considered. Joint failure is defined to include joint slip or separation and broken bolts or joint members. The vibration loosening mechanism is explained; methods for maintaining the friction grip or preventing relative slip are given. The author explains the sequence of fatigue failure and the appearance of fatigue breakage. He discusses the factors that determine fatigue life and the influence of bolt pre-load and joint stiffness. Problems with gasket joints -- such as obtaining satisfactory flange surfaces and flange pressure distribution -- are also discussed; recommendations for producing leak free joints are made. Methods for minimizing corrosion problems are also mentioned. The author concludes with a chapter containing answers to the questions most designers ask when specifying a joint: the corect pre-load, the bolt torque or stretch to be specified, and the likely mode of joint failure.

The text is punctuated by interesting and relevant case studies that are concerned mainly with large fasteners, such as those found in pressure vessels, pipe joints, and heat exchangers. There is not much specific information on structural steel joints, although most of the information is relevant to this type of joint. A list of references is given at the end of each chapter. Useful appendices on a range of joint parameters include bolt specifications, tools, and material strengths. Although vibration is considered from the viewpoint of loosening bolted joints, no mention is made of damping in joints or the effect that bolt pre-load in joints can have on the dynamic response of structures. Temperature effects and creep in bolts also merit greater consideration.

Overall however, this is a useful handbook on bolted joints that many designers will want to own.

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FRETTING FATIGUE

R.B. Waterhouse, Editor
Applied Science Publ., Barking, Essex, England
1981; 244 pp

Fatigue is a primary cause of component failure. In the last 25 years fretting fatigue has become recognized as a prime factor in the failure of rotating machine components, airplane pin-bore fittings, wire rope, flanges, and double strap joints. Fretting damage occurs on contacting surfaces of components that are clamped together and, although normally at rest relative to each other, are subject to vibration. Repeated alternating slippage of the surface over part of the mutual contact area can cause fretting damage and ultimately fatigue. Fretting can override geometric stress concentrations and initiate cracks. Experimental evidence has shown that fretting exerts a much greater effect on fatigue strength at low stresses and long life; i.e., so-called high cycle fatigue. The problem is to reduce or possibly eliminate the effect of fretting on fatigue. This little book explains the basis of fretting fatigue and how it can be mastered.

The book contains nine chapters written by seven experts in the field. The editor contributed four chapters. The first chapter introduces the general subject of fatigue: fatigue reduction factor (K_s), stress concentration (K_1), and an introduction to fracture mechanics. The second chapter considers the elastic stress analysis required to interpret fretting fatigue failures. Most of the chapter refers to the author's published work on the subject. Among the topics are analytical and experimental work on stress fields (tension, bending, and torsion). The chapter concludes with a brief discussion of mechanisms involved in fretting fatigue.

Chapter 3 focuses on the application of fracture mechanics in predicting fretting fatigue. Stress intensity factors are defined, crack rates are calculated, and fracture mechanics is used to predict constant and variable amplitude loading. The author shows that, for random loading, the fatigue strength for the fretting condition has much shorter life than constant amplitude. This is similar to common fatigue loading findings. The reviewer would have preferred more illustrative examples of the prediction methods developed by the author.

Chapter 4 describes the occurrence of fretting fatigue. Specific examples include flange face fretting, pin-bore fretting, wire rope and control cable failure, and fitting fatigue failure.

Chapter 5 considers initiation and propagation of fretting fatigue cracks. A number of photographs show fretting fatigue initiation and propagation.

Chapter 6 focuses on environmental effects in fretting fatigue. Subjects include stress corrosion, corrosion fatigue, wear, galling, overload, embrittlement (gaseous and neutron), and aging. The various theories mentioned are Uhleg, Wright, and Waterhouse.

Chapter 7 describes fretting fatigue in aqueous electrolytes and the deleterious effects of salt solutions and cathodic effects on fretting. Interestingly, the higher the frequency the less catastrophic the fretting fatigue.

Chapter 8 describes fretting fatigue in high temperature oxidizing gases. Titanium alloys comprise a main portion of this chapter. Iron-based and nickel-based alloys are also considered. Techniques that increase fretting fatigue strength, including shot peening, diffusion bonding of chromium and nickel, and high velocity plasma spray, are given.

Chapter 9, written by the editor, has to do with the various theories of fretting fatigue processes. He explains that interaction sites for fatigue cracks are points of particular stress concentrations; e.g., at the boundary between slip and non-slip regions or at or near the outer contact boundary. The initial rate or growth of a fatigue crack is increased by additional alternating shear stress but slows when the crack propagates out of the region influenced by fretting contact. This excellent chapter contains photographs of microstructures.

The last chapter shows how fretting fatigue failures can be avoided or reduced in intensity. A number of design hints are applied to dovetails and to metallic and non-metallic coatings, implantation, and ion plating. The use of lubricants and their reduced effectiveness with time are explained. Surface cold properly applied will increase the life of a specimen that is subject to fretting fatigue.

In summary, this is an excellent book. The designer can benefit from the book and become aware of ways for decreasing the deleterious effects of fretting fatigue.

H. Saunders
General Electric Company
Building 41, Room 307
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SHORT COURSES

NOVEMBER

MACHINERY VIBRATION ANALYSIS

Dates: November 9-12, 1982
Place: Oak Brook, Illinois
Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation, and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow-speed paper rolls.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

20TH ANNUAL RELIABILITY ENGINEERING AND MANAGEMENT INSTITUTE

Dates: November 15-19, 1982
Place: Tucson, Arizona
Objective: Emphasis will be on reliability engineering theory and practice; mechanical reliability prediction; reliability testing and demonstration, reliability data sources, maintainability engineering, and life cycle costing; product liability; reliability and maintainability management, and life-cycle costing.

Contact: Dr. Dimitri Kececioglu, Reliability Engineering and Management Institute, Aerospace and Mechanical Engineering Department, Building 16, The University of Arizona, Tucson, AZ 87521 - (602) 626-2495.

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: November 15-19, 1982
Place: Santa Barbara, California
Dates: December 8-12, 1982
Place: Huntsville, Alabama
Dates: February 7-11, 1983
Place: Santa Barbara, California
Dates: March 7-11, 1983
Place: Washington, DC
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (805) 682-7171.

FEBRUARY

SYSTEMATIC APPROACH TO IMPROVING MACHINERY RELIABILITY IN PROCESS PLANTS

Dates: February 23-25, 1983
Place: San Francisco, California
Objective: This seminar is intended to guide machinery engineers, plant designers, maintenance administrators, and operating management toward results-oriented specifications, selection, design review, installation, commissioning, and post start-up management of major machinery systems for continued reliable operations. Emphasis will be on pumps, compressors, and drivers.

Contact: Sherry Theriot, Professional Seminars International, P.O. Box 156, Orange, TX 77630 - (713) 746-3506.

ABSTRACTS FROM THE CURRENT LITERATURE

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ABSTRACT CONTENTS

MECHANICAL SYSTEMS

ROTATING MACHINES

(Also see Nos. 2108, 2109, 2265, 2282, 2283)

82-2057
Current Topics in Rotordynamics Research
J.W. Lund
Afdelingen for Maskinelementer, Bygning 403, Danmarks Tekniske Hojskole, 2800 Lyngby, Denmark, Shock Vib. Dig., 14 (6), pp 3-7 (June 1982) 39 refs

Key Words: Rotors, Flexible rotors, Whirling, Reviews

This article describes destabilizing effects due to passive forces on flexible rotors. Recent advances in modeling rotor/bearing systems are also summarized.

82-2058
On the Instability of Rotating Shafts Due to Internal Damping
L.L. Bucciarelli
School of Engrg., Massachusetts Inst. of Tech., Cambridge, MA 02139, J. Appl. Mech., Trans. ASME, 49 (2), pp 425-428 (June 1982) 2 figs, 10 refs

Key Words: Shafts, Internal damping, Stability

Internal damping in rotating shafts can lead to dynamic instability – the unbounded growth over time of the off-axis displacement of the spinning shaft in whirl. In analyzing this phenomenon, some authors have phrased the instability criterion in terms of energies dissipated through internal and external damping. One such study has claimed that instability ensues when the rate of work done by internal damping equals that done by external damping. This analysis shows that this criterion is wrong and explains why it fails. It also provides a clear picture of how internal forces can act to produce instability by coupling the motion of spin with motion in whirl.

82-2059
Experiments on the Stability and Response of a Flexible Rotor in Three Types of Journal Bearings
R.F. Lanes, R.D. Flack, and D.W. Lewis
Univ. of Virginia, Charlottesville, VA 22901, ASLE Trans., 25 (3), pp 289-298 (July 1982) 15 figs, 1 table, 17 refs

Key Words: Rotors, Flexible rotors, Bearings, Journal bearings, Dynamic tests, Stability, Unbalanced mass response

Three sets of bearings were tested on a three-mass flexible rotor: axial-groove, pressure-dam and preloaded three-lobe. The instability thresholds and unbalance responses were determined. The pressure-dam bearings were designed for maximum rigid rotor stability; the three-lobe bearings had preload factors of approximately 0.75. The experimental data were compared to theoretical predictions. Differences in instability thresholds of up to 37 percent were realized.

82-2060
Static and Dynamic Investigations for the Model of a Wind Rotor
J.H. Argyris, K.A. Braun, B. Kirchgaessner, and R. Walther
Inst. f. Statik und Dynamik der Luft- und Raumfahrtkonstruktionen, Stuttgart Univ., Fed. Rep. Germany, Rept. No. ISD-272, ISD-259, 71 pp (1980) (English transl. of "Statische und Dyn. Untersuch. And Einem Windrotormodell," Stuttgart Univ., Stuttgart, June 1979, 69 pp)
N82-17642

Key Words: Rotors, Wind mills, Measurement techniques, Variable material properties, Time-dependent parameters

A wind rotor was constructed in order to test a data acquisition/transfer system which collects experimental data from the operating model and displays it on a screen. The comparison between the experimental data and the model results is used to check the applied computation methods. The static and dynamic analyses of the rotor model are considered. An 11% difference between experimental and model results is shown. A response problem with variable stiffness in time which arose during the dynamic analysis is solved.

82-2061
A Dynamic Model for Rotary Rock Drilling
I.E. Eronini, W.H. Somerton, and D.M. Auslander
Howard Univ., Washington, DC 20059, J. Engrg. Resources Tech., Trans. ASME, 104 (2), pp 108-120 (June 1982) 22 figs, 2 tables, 23 refs

Key Words: Drills, Rocks, Torsional vibration, Mathematical models

A rock drilling model is developed as a set of ordinary differential equations describing discrete segments of the drilling rig, including the bit and the rock. The end segment consists of a description of the bit as a "nonideal" transformer and a characterization of the rock behavior. The effects on rock drilling of bottom hole cleaning, drill string-borehole interaction, and tooth wear are represented in the model. Simulated drilling under various conditions, using this model, gave results which are similar to those found in field and laboratory drilling performance data. In particular, the model predicts the expected relationships between drilling rate and the quantities, weight on bit, differential mud pressure, and rotary speed.

82-2062

Spin Test Vibrations of Pendulously Supported Disc/Cylinder Rotors

F.H. Wolff and A.J. Molnar

Westinghouse R&D Ctr., Pittsburgh, PA, Shock Vib. Bull. 52, Part 1, pp 95-100 (May 1982) 7 figs, 1 table, 3 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Rotors, Disks (shapes), Cylinders, Forced vibration

Forced vibration levels of disc and cylindrical shaped rotors as they are brought up to speed are calculated. The danger of spinning a pendulously supported rotor whose polar and diametral mass moments of inertia are nearly equal is analyzed and explained.

82-2063

The Use of Resonators to Silence Centrifugal Blowers

G.H. Koopmann and W. Neise

Dept. of Mech. Engrg., Univ. of Houston, Houston, TX 77004, J. Sound Vib., 82 (1), pp 17-27 (May 8, 1982) 9 figs, 2 refs

Key Words: Blowers, Resonators, Noise reduction

The casing of a 235 mm diameter, commercially produced, centrifugal blower was modified by replacing the cut-off of the scroll with a quarter-wavelength resonator. The mouth of the resonator was formed from a perforated plate which had the same curvature as the original cut-off section. Tuning of the resonator was achieved by changing the length via a movable end plug. Noise measurements were made in anechoically terminated inlet and outlet ducts over a range of aerodynamic loading conditions. It was found that the extent of the reductions in the blade passing frequency tones in both the inlet and outlet duct varied with the orientation of and the extent of open area on the mouth perforate. By introducing a splitter in the resonator mouth, substantial reductions in both the inlet and outlet duct were achieved over a large range of aerodynamic loading.

82-2064

Dynamic Analysis of a Rotor Blade with Flap and Lag Freedom and Flap-Pitch Coupling

J.H. Argyris, K.A. Braun, and B. Kirchgaessner

Inst. f. Statik und Dynamik der Luft- und Raumfahrtkonstruktionen, Stuttgart Univ., Fed. Rep. Germany, Rept. No. ISD-271, ISD-258, 103 pp (1980)

N82-17641

Key Words: Propeller blades, Dynamic analysis

For a windmill rotor blade, a linearized system of differential equations of motion is developed, using a finite element idealization of linearized quasi-stationary aerodynamic forces. Constant rotational speed and a rigidly supported hub are assumed. For two rotor blade models, which differ only in their stiffness in lag direction, the complex eigenfrequencies are calculated. The dynamic response of the rotor blades is computed for cyclic gravity loads at rated operation, for a gust, and, in one case, for the tower wake. From the deformation of the structure the stresses at selected points along the blade are calculated. Torque and rotor thrust are determined for one model.

82-2065

Dynamic Response of Hovercraft Lift Fans

D.D. Moran

Div. of Engrg. and Weapons, Naval Academy, Annapolis, MD, Rept. No. USNA-EW-12-81, 19 pp (Aug 1981)

AD-A110 883

Key Words: Fans, Ground effect machines

Hovercraft lift fans are subjected to varying back pressure due to wave action and craft motions when these vehicles are operating in a seaway. The oscillatory back pressure causes the fans to perform dynamically, exhibiting a hysteresis type of response and a corresponding degradation in mean performance. Since hovercraft motions are influenced by variations in lift fan pressure and discharge, it is important to understand completely the nature of the dynamic performance of lift fans in order to completely solve the hovercraft seakeeping problem. The present study was performed to determine and classify the instabilities encountered in a centrifugal fan operating against time-varying back pressure. A model-scale experiment was developed in which the fan discharge was directed into a flow-measuring device, terminating in a rotating valve which produced an oscillatory back pressure superimposed upon a mean aerodynamic resistance. Pressure and local velocity were measured as functions of time at several locations in the fan volute.

82-2066

About the Calculation of Tonal Components within the Sound Power Spectrum of Axial-Flow Fans (Zur Berechnung tonaler Komponenten im Schalleistungsspektrum von Axialventilatoren)

P. Kõltzsch, S. Gruhl, J. Plundrich, and M. Heinze

Bergakademie Freiberg, Sektion Maschinen- und Energietechnik, Wissenschaftsbereich Grundlagen der Energieumwandlung, Maschinenbautechnik, 31 (4), pp 148-154 (Apr 1982) 8 figs, 4 tables, 18 refs

(In German)

Key Words: Fans, Sound power levels

An engineering calculation method is shown by which the sound power of tonal components of an axial-flow machine can be calculated from the machine characteristics. According to the physical sequence of sound origin equations for different lattice arrays and acoustic lattice models are stated. Forty measured values of discrete components have been compared with the calculated values.

82-2067

Seismic Analysis of Rotating Mechanical Systems – A Review

V. Srinivasan and A.H. Soni

School of Mech. and Aerospace Engrg., Oklahoma State Univ., Stillwater, OK 74078, Shock Vib. Dig., 14 (6), pp 13-19 (June 1982) 7 figs, 18 refs

Key Words: Rotating machinery, Seismic analysis, Reviews

The need to design reliable machines for earthquake environments has focused attention on the seismic analysis of rotating mechanical systems. This article reviews the available literature in this area and presents the models used and results obtained by various authors.

82-2068

Contribution to the Dynamic Behaviour of Flexible Mechanisms

E. Imam, J. Der Hagopian, and M. Lalanne

Inst. National des Sciences Appliquées, Laboratoire de Mécanique des Structures E.R.A. C.N.R.S. 911, Villeurbanne, France, Shock Vib. Bull. 52, Part 1, pp 125-133 (May 1982) 11 figs, 20 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Mechanisms, Four bar mechanisms, Rotating structures, Beams, Finite element technique

In high speed rotating mechanisms links cannot be taken as perfectly rigid. In this paper general expressions for kinetic and strain energies of deformable plane rotating mechanisms are presented. The differential equations of the system are obtained using finite element techniques. The number of degrees of freedom of the system is reduced by a modal method and the solution of the system is obtained from a closed form algorithm taking into account the motion periodicity. A four bar system was tested. In order to reduce stresses and strains, damping has been introduced by a viscoelastic sandwich treatment. The agreement between experimental and theoretical results is satisfactory for both the damped and undamped system.

RECIPROCATING MACHINES

82-2069

Reduction of Hydraulic Line Oscillating Pressures Induced by Pump Cavitation

G. Druhak, P. Marino, and M. Bernstein

Grumman Aerospace Corp., Bethpage, NY, Shock Vib. Bull. 52, Part 4, pp 103-121 (May 1982) 29 figs, 2 tables, 6 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Aircraft, Hydraulic systems, Pumps, Cavitation, Helmholtz resonators

A Helmholtz resonator cavitation attenuator was developed to reduce oscillating pressure and resulting vibration induced stresses. Its development, the magnitude of reduction it effected in hydraulic line and bracket stresses, and the analytic procedure to calculate the standing pressure wave induced stresses in hydraulic lines are described.

82-2070

Source Identification on a Diesel Engine Using Acoustic Intensity Measurements

T.E. Reinhart and M.J. Crocker

Cummins Engine Co., Inc., MS 71400, Columbus, IN 47201, Noise Control Engrg., 18 (3), pp 84-92 (May-June 1982) 13 figs, 1 table, 21 refs

Key Words: Noise source identification, Diesel engines, Engine noise

The acoustic intensity method is demonstrated in both ideal and practical experimental measurements. Results of a noise source identification of a diesel engine are compared with results obtained by surface intensity and lead-wrapping measurements. Acoustic intensity is shown to be a reliable, informative and useful tool for noise source identification. Errors involved in the method are also discussed.

82-2071

The Causes for Diesel Engine Knocking (Über die Ursachen des Klopfens bei Kammerdieselmotoren)

G. Akiskalos

Fortschritt-Berichte VDI-Z, Series 6, No. 93, 160 pp (1981) 54 figs, 3 tables, 91 refs. Avail: VDI-Verlag GmbH, Postfach 1139, 4000 Dusseldorf 1, Germany. Price 91.00 DM

(In German)

Key Words: Diesel engines, Engine noise, Noise generation

In a series of tests the effect of various parameters on the knocking of diesel engines were investigated. The noise seems to be generated by the contact of pistons and the cylinder; i.e., lateral vibration of the pistons caused by an eccentric gas pressure, producing the characteristic sound.

POWER TRANSMISSION SYSTEMS

(See No. 2284)

STRUCTURAL SYSTEMS

BRIDGES

(Also see No. 2205)

82-2072

Theoretical Analysis of Infrasound Radiation from an Oscillating Bridge

K. Imaichi, Y. Tsujimoto, and S. Takabatake

Dept. of Mech. Engrg., Osaka Univ., Toyonaka, Osaka, Japan, J. Sound Vib., 81 (4), pp 453-468 (Apr 22, 1982) 9 figs, 1 table, 11 refs

Key Words: Bridges, Sound propagation, Lifting surface theory

As a typical example of the sound radiation caused by the oscillation of a large sized structure, the infrasound radiation from a highway bridge is theoretically analyzed by applying a lifting surface technique. The relation between the bridge oscillation and the corresponding infrasound radiation is made clear quantitatively. By using measured results of the bridge oscillation due to the passage of a vehicle, the infrasound radiated from the bridge is estimated analytically. The results are compared with the measurements, and good agreement is seen.

82-2073

Curved Bridge Response to a Moving Vehicle

J. Genin, E.C. Ting, and Z. Vafa

Dept. of Mech. Engrg., New Mexico State Univ., Las Cruces, NM 88003, J. Sound Vib., 81 (4), pp 469-475 (Apr 22, 1982) 6 figs, 5 refs

Key Words: Bridges, Moving loads

An algorithm is developed for the solution of the dynamic displacement and rotation of a horizontal curved guideway (bridge) as it interacts with a traversing vehicle. The algorithm is validated against experimental results, and a parametric study is presented.

82-2074

Bridge Loading: Research Needed

The Committee on Loads and Forces on Bridges of the Committee on Bridges of the Structural Div., ASCE J. Struc. Div., 108 (5), pp 1012-1020 (May 1982) 3 refs

Key Words: Bridges, Moving loads, Fatigue life

The need for research in areas of bridge loading is examined. It is argued that one reason research is incomplete is poor definition of the requirements. The main priorities for research are defined. Subjects for research include traffic loading for both long and short span bridges, braking, or longitudinal, forces, fatigue, and environmental effects. Research problems are given.

82-2075

Simplified Earthquake Analysis of Suspension Bridge Towers

A.M. Abdel-Ghaffar and J.D. Rood

Civil Engrg. Dept., Princeton Univ., Princeton, NJ, ASCE J. Engrg. Mech. Div., 108 (2), pp 291-308 (Apr 1982) 16 figs, 4 tables, 8 refs

Key Words: Bridges, Suspension bridges, Towers, Seismic response

Free vibration and earthquake response analyses of a simplified continuous analytical model representing suspension bridge towers (fixed at the base) are presented. In addition, various models for seismic analysis of the towers are proposed. These models take into account, among other things, the flexibility of the surrounding soils and the multiple-seismic inputs. The earthquake response of some existing suspension bridges' towers is analyzed, and stresses (both vibrational and quasi-static) induced by different earthquake ground motions are examined. Both time history response and the classical response spectra are considered.

82-2076

Suspension Bridge Response to Multiple-Support Excitations

A.M. Abdel-Ghaffar and L.I. Rubin

Civil Engrg. Dept., Princeton Univ., Princeton, NJ, ASCE J. Engrg. Mech. Div., 108 (2), pp 419-435 (Apr 1982) 10 figs, 3 tables, 8 refs (Pres. at the May 11-15, 1981 New York Intl. Convention)

Key Words: Bridges, Suspension bridges, Seismic excitation, Earthquakes

The earthquake-induced vertical response of suspension bridges when subjected to multiple-support excitations is analyzed by means of random vibration theory. Appropriate ground motions describing the basic inputs to such structures are defined through finite Fourier transforms of existing recorded ground displacements at locations within distances similar to the spans of such structures. Spectral correlation analysis of the multiple-support excitations are estimated via these Fourier transforms. It is found that studies of earthquake-induced vertical motion of suspension bridges need to take into account the influences of ground excitations in the longitudinal directions of such bridges.

BUILDINGS

82-2077

Acrosswind Response of Buildings

A. Kareem

Dept. of Civil Engrg., Univ. of Houston, Houston, TX, ASCE J. Struc. Div., 108 (4), pp 869-887 (Apr 1982) 10 figs, 25 refs

Key Words: Buildings, Wind-induced excitation, Random vibration

The acrosswind response of buildings is investigated. Expressions for the acrosswind loading are developed through the use of the spatio-temporal measurement of the fluctuating pressure field around a square cross-section building model. Methods of random vibration theory are used to estimate the rms and peak values of displacement, acceleration and jerk components of response. The results are compared with the response of an aeroelastically modeled building. The predicted and measured response agree within the limits of expected experimental errors.

82-2078

Response of Friction Damped Braced Frames

A.S. Pall and C. Marsh

The SNC Group, 1 Complex Desjardins, Montreal, Quebec, Canada, ASCE J. Struc. Div., 108 (6), pp 1313-1323 (June 1982) 12 figs, 18 refs

Key Words: Buildings, Framed structures, Steel, Seismic design, Coulomb friction

A new concept of aseismic design for steel framed buildings is proposed. By providing sliding friction devices in the bracing system of the framed buildings, their earthquake resistance and damage control potential can be considerably enhanced. During severe earthquake excitations, the friction device slips and a large portion of the vibrational energy is dissipated mechanically in friction rather than inelastic yielding of the main structural components. Results of inelastic time-history dynamic analysis show superior performance of the friction damped braced steel frames when compared to computed responses of other structural framing systems.

82-2079

Linearization Methods in Earthquake Analysis and Design of Hysteretic Structural Systems

Y. Bozorginia
Ph.D. Thesis, Univ. of California, Berkeley, 146 pp (1981)
DA8211831

Key Words: Buildings, Earthquake resistant structures, Seismic design

In most buildings and structures designed to resist earthquake attack the protection of the structure is effected by inelastic deformation of structural elements and the energy dissipation that is produced by this inelastic behavior. It is therefore desirable in the design process, to have efficient and reliable approximate procedures to estimate the nonlinear dynamic behavior of the structure. This dissertation is concerned with the development of linearization methods, suitable for the earthquake analysis and design of yielding structures, to provide predictions of the actual nonlinear behavior of these structures. Current linearization techniques use conventional viscous damping model as the equivalent linear model for the nonlinear structure, and apply different approximation methods to determine the effective parameters of the linear model. However, there are several deficiencies in using the conventional model as the equivalent linear system. These deficiencies are described qualitatively and quantitatively in this investigation. An alternative equivalent linear model for the hysteretic structures is proposed.

82-2080

Vertical Seismic Load Effect on Building Response

Y.K. Lin and T.-Y. Shih
Univ. of Illinois at Urbana-Champaign, Urbana, IL, ASCE J. Engrg. Mech. Div., 108 (2), pp 331-343 (Apr 1982) 6 figs, 16 refs

Key Words: Buildings, Seismic response

An analytical procedure is presented for the calculation of the statistical properties of the response of a linear elastic tall building under earthquake excitations. The emphasis is placed on the effect of the vertical ground motion. The restoring force in each story of the structural model is assumed to arise from the bending deformation of the columns whose rigidities are subject to a general reduction due to gravitational forces and to a random variation due to vertical ground accelerations. To illustrate the application of the procedure, numerical results are presented for a six-story building.

82-2081

The Response of Veterans Hospital Building 41 in the San Fernando Earthquake

A. Rutenberg, P.C. Jennings, and G.W. Housner
Technion, Israel Inst. of Tech., Haifa, Israel, Earthquake Engrg. Struc. Dynam., 10 (3), pp 359-379 (May-June 1982) 9 figs, 10 tables, 25 refs

Key Words: Buildings, Earthquake damage

During the 9 February, 1971 San Fernando earthquake, Building 41 of the Veterans Administration Hospital was in an area of very strong shaking, being directly over a portion of the causative fault. It is estimated that the building experienced a maximum base shear of 60 to 130 per cent of the weight of the structure. It survived with very minor structural damage, although designed with a lateral force coefficient of only 10 per cent. The study attempts to reconcile these facts by analysis of the transverse response of the building.

82-2082

Investigation of the Elastic Characteristics of a Three-Storey Steel Structure Using System Identification

I. Kaya and H.D. McNiven
Ege Univ., Izmir, Turkey, Earthquake Engrg. Struc. Dynam., 10 (3), pp 433-445 (May-June 1982) 4 figs, 5 refs

Key Words: Buildings, Multistory buildings, System identification techniques, Seismic response

In this report, three different models in increasing order of complexity have been used to identify the seismic behavior of a three-story steel structure subjected to arbitrary forcing functions, all of which excite responses within the elastic range. All of the models are constructed using system identification.

82-2083
Stochastic Response of Multistorey Yielding Frames
T.T. Baber and Y.-K. Wen
Univ. of Virginia, Charlottesville, VA, Earthquake Engrg. Struc. Dynam., 10 (3), pp 403-416 (May-June 1982) 12 figs, 3 tables, 13 refs

Key Words: Buildings, Multistory buildings, Random vibration, Stochastic processes

A model for the random vibration of hysteretic and degrading plane frames to Gaussian shot noise or filtered shot noise is presented. The model, which combines the discrete hinge concept previously used in deterministic frame analysis with Bouc's smooth system hysteresis, results in a nonlinear set of differential equations which can be linearized in closed form without recourse to the Krylov-Bogoliubov assumptions. Solution is iterative in the stationary case and by numerical integration with stepwise updates in the nonstationary case. Numerical studies are presented of strong girder and strong column two story, one bay frames. These studies indicate that the model can locate the sites of yielding and provide reasonable values of structural response as compared with simulation data.

TOWERS

(Also see Nos. 2186, 2230)

82-2084
Static and Dynamic Investigations of Different Towers for Wind Turbines
J.H. Argyris and K.A. Braun
Inst. f. Statik und Dynamik der Luft- und Raumfahrtkonstruktionen, Stuttgart Univ., Fed. Rep. Germany, Rept. No. ISD-274, ISD-261, 125 pp (1980)
N82-17637

Key Words: Towers, Cantilever beams, Guyed structures, Wind turbines, Wind induced excitation

The kinematics of a cantilevered, a conventional guyed, and a compliant (elastic column held by a rigid framework) tower were studied. The static layout of the towers is established, using the reactions due to different gusts which a two-bladed rotor imposes on a rigid support as external loads.

82-2085
Nonlinear Travleing-Wave Effects on Cooling Tower
J.P. Wolf and K.M. Bucher
Struc. Dynam. Div., Electrowatt Engrg. Services Ltd., Bellerivestrasse 36, Zurich, Switzerland, ASCE J. Struc. Div., 108 (6), pp 1424-1437 (June 1982) 16 figs, 2 tables (Pres. at the May 11-15, 1981 ASCE Annual Convention, Exposition and Continuing Education Program, held at New York, NY)

Key Words: Towers, Cooling towers, Reinforced concrete, Seismic design

The dynamic response of a tall reinforced-concrete hyperbolic cooling tower which has been designed for vertically incident seismic waves, based on a linear analysis, is examined for horizontally propagating waves of the same amplitude. The nonlinear response is also calculated, taking into account the material law of the reinforcing steel and of the concrete in the columns as well as lift-off and slipping of the separate foundations.

FOUNDATIONS

82-2086
Seismic Soil-Pile-Structure Interaction, Pile Groups
T. Kagawa
McClelland Engineers, Inc., Houston, TX, Rept. No. NSF/CEE-81081, 86 pp (Aug 1981)
PB82-171471

Key Words: Interaction: soil-structure, Pile structures, Seismic response, Beams, Winkler foundations

A parametric study is presented of dynamic pile-group effects for an idealized soil-pile-structure system consisting of a lumped mass model of a superstructure and elastic piles fully embedded in a homogeneous, linearly elastic soil layer. The results are used to develop an approximate method, based upon a beam-on-Winkler foundation model, that can be used for dynamic response analyses of pile-groups in layered elastic soils. The approximate pile-group method is evaluated by comparing computed and observed seismic response data of a building supported by a group of piles. The comparison shows that the dynamic stiffness and damping characteristics of a pile group can be evaluated correctly using the procedure.

82-2087
Impedance Matrices and Interpolation Techniques for 3-D Interaction Analysis by the Flexible Volume Method
F.F. Tajirian

Ph.D. Thesis, Univ. of California, Berkeley, 169 pp (1981)
DA8212120

Key Words: Interaction: soil-structure, Frequency domain method, Computer programs

Most currently available procedures for the dynamic analysis of three dimensional soil-structure systems have some restrictions regarding the type of system that can be analyzed. Hence, a new technique, the flexible volume method, has been developed. This method can handle much more complex problems than current methods of analysis. It can handle flexible foundations of arbitrary shapes embedded in a layered viscoelastic halfspace, structure to structure interaction, and pile foundations. The only limitation is cost and available computer storage space.

82-2088
Resistance of a Soil Layer to Horizontal Vibration of a Pile
M.T. Nielsen
Dept. of Struc. Engrg., Technical Univ. of Denmark, Lyngby, Denmark, Earthquake Engrg. Struc. Dynam., 10 (3), pp 497-510 (May-June 1982) 6 figs, 6 refs

Key Words: Pile structures, Off-shore structures, Soils, Damped structures, Hysteretic damping

The resistance of a soil to horizontal harmonic vibration of a vertical, end bearing pile with circular cross-section is theoretically investigated. The soil is considered to be a continuum with material damping of the hysteretic type. The motion of the soil and pile are expressed as series, and a resistance coefficient on each term in the series of the pile motion is found. The resistance is found to depend on the excitation frequency, the pile slenderness and on the material properties of the soil. A study of the influence of the parameters is carried out.

UNDERGROUND STRUCTURES

(See Nos. 2239)

HARBORS AND DAMS

82-2089
Three-Dimensional Dynamic Response Analysis of Earth Dams
L.H. Mejia
Ph.D. Thesis, Univ. of California, Berkeley, 258 pp (1981)
DA8212040

Key Words: Dams, Dynamic response

Many earth dams exist for which the assumption of plane strain conditions during dynamic loading constitutes only an approximation of their true behavior. Therefore, it seems that in these cases, a full three-dimensional dynamic response analysis is warranted. The purpose of the present work is to develop numerical techniques for the three-dimensional dynamic analysis of earth and rockfill dams and to study the dynamic behavior of embankment dams in three dimensions.

82-2090
Vibration Tests on Emosson Arch Dam, Switzerland
P.J. Deinum, R. Dungar, B.R. Ellis, A.P. Jeary, G.A.L. Reed, and R.T. Severn
Motor Columbus, Switzerland, Earthquake Engrg. Struc. Dynam., 10 (3), pp 447-470 (May-June 1982) 27 figs, 3 tables, 11 refs

Key Words: Dams, Vibration tests, Wind-induced excitation, Vibrators (machinery), Seismic design

Measurements have been made of vibrations induced in the 180 m high Emosson arch dam in Switzerland by a system of mechanical eccentric-mass vibrators and by the natural wind. Details are given of the dam itself, the tests and the experimental results obtained. Finite element calculations made before the tests, which include reservoir and foundation effects, are compared with the measurements.

82-2091
Hydrodynamic Effects in Dynamic Response of Simple Arch Dams
C.S. Porter and A.K. Chopra
Dept. of Civil Engrg., Univ. of California, Berkeley, CA, Earthquake Engrg. Struc. Dynam., 10 (3), pp 417-431 (May-June 1982) 13 figs, 2 tables, 6 refs

Key Words: Dams, Hydrodynamic excitation

The dynamic responses of simple arch dams, with different radius to height ratios are analyzed for three conditions: the dam alone without water, and the dam with full reservoir, considering water to be compressible in one case and neglecting water compressibility in the other case. The complex frequency response functions for accelerations at the dam crest due to the three components of ground motion -- upstream-downstream component, cross-stream component and vertical component -- are presented. Based on these results, the effects of dam-water interaction, of water compressibility, and of bank motions on dam response are investigated.

82-2092
Boundary Element Analysis of Fluid Domain
Y.G. Hanna and J.L. Humar
Dept. of Civil Engrg., Carleton Univ., Ottawa, Ontario, Canada, ASCE J. Engrg. Mech. Div., 108 (2), pp 436-450 (Apr 1982) 10 figs, 18 refs

Key Words: Dams, Hydrodynamic excitation, Boundary element technique

The boundary element method of analysis is applied to the calculation of hydrodynamic pressures in a reservoir impounded by a gravity dam and subjected to a harmonic ground motion. It is shown that the differential equation governing the small amplitude vibrations of the reservoir reduces to the familiar Helmholtz equation. This equation is converted to an integral equation which involves integrations only on the boundary of the reservoir. The integrals are evaluated numerically by using a series of straight line elements to represent the boundary. The resulting simultaneous equations are solved by standard techniques to obtain the pressures and pressure derivatives on the boundary. Analytical results are presented to show that the proposed method gives results that are in good agreement with the known classical solutions. The method is then applied to the solution of vibration problems of reservoirs with irregular boundaries for which classical solutions do not exist.

CONSTRUCTION EQUIPMENT

82-2093
Fatigue Design in Mining Size Reduction Equipment
V. Svalbonas
Koppers Co., Inc., Mineral Processing Systems Div., York, PA 17405, J. Pressure Vessel Tech., Trans. ASME, 104 (2), pp 104-119 (May 1982) 18 figs, 10 refs

Key Words: Mining equipment, Fatigue strength

The mining size reduction equipment industry is reviewed regarding efforts to obtain a consistent fatigue design philosophy. Serious structural failures, which have prompted various company efforts in this area, are reviewed. Efforts to obtain design criteria have been hampered by lack of data concerning the mundane materials, such as cast iron, used in the fabrications. Similar research from high technology industries, therefore, does not provide directly applicable data. However, new testing efforts are underway, and basic fatigue data is being gathered with the goal of providing consistent design, fabrication and nondestructive examination programs.

POWER PLANTS

(See Nos. 2223, 2262)

OFF-SHORE STRUCTURES

(Also see Nos. 2088, 2172)

82-2094
Local Member Response in Offshore Structures under Earthquake Excitations
S.A. Anagnostopoulos and A.R. Culbertson
Inst. of Engrg., Seismology and Earthquake Engrg., HAPSA 1, Thessaloniki (7063), Greece, Earthquake Engrg. Struc. Dynam., 10 (3), pp 349-358 (May-June 1982) 4 figs, 3 tables, 5 refs

Key Words: Off-shore structures, Joints (junctions), Seismic excitation, Earthquakes

It is shown that local vibrations of certain members in earthquake excited offshore structures can induce substantial stresses that may often dominate the design of these members. Such vibrations are not accounted for in dynamic analyses of structural models with masses lumped at the joints. A practical, easy to implement solution to this problem is recommended and results from an actual structure, subjected to a three-component real earthquake, are presented demonstrating the importance of local inertia effects.

VEHICLE SYSTEMS

GROUND VEHICLES

(Also see Nos. 2152, 2284)

82-2095
Vibrations of a Periodic Rail-Sleeper System Excited by an Oscillating Stationary Transverse Force

M.L. Munjal and M. Heckl
Dept. of Mech. Engrg., Indian Inst. of Sci., Bangalore 560012, India, J. Sound Vib., 81 (4), pp 491-500 (Apr 22, 1982) 8 figs, 1 table, 11 refs

Key Words: Rail-sleeper systems, Mass-beam systems, Periodic structures, Wave propagation

The rail-sleeper system is idealized as an infinite, periodic beam-mass system. Use is made of the periodicity principle for the semi-infinite halves on either side of the forcing point for evaluation of the wave propagation constants and the corresponding modal vectors. It is shown that the spread of acceleration away from the forcing point depends primarily upon one of the wave propagation constants. However, all four modal vectors determine the driving point impedance of the rail-sleeper system, which in combination with the driving point impedance of the wheel determines the forces generated by combined surface roughness and the resultant accelerations. The compound one-third octave acceleration levels generated by typical roughness spectra are generally of the same order as the observed levels.

82-2096
Propagation of Road Traffic Noise over Level Terrain

K.B. Rasmussen
The Acoustics Lab., Technical Univ. of Denmark, DK-2800 Lyngby, Denmark, J. Sound Vib., 82 (1), pp 51-61 (May 8, 1982) 10 figs, 17 refs

Key Words: Traffic noise, Sound propagation

Propagation of road traffic noise over level terrain is treated from a theoretical point of view. The starting point is taken to be sound propagation from a point source over two semi-infinite half planes joined along a straight line. This is the basic situation involved in a road traffic noise calculation since the road surface is much harder from an acoustic point of view than the surrounding terrain (fields or lawns). A mathematical model describing this point source situation is given and verified by loudspeaker measurements. This model is then used for the road traffic noise situation and the theoretical excess attenuation is compared to values obtained from road traffic noise measurements.

SHIPS
(Also see Nos. 2065, 2171, 2224)

82-2097
Propeller Design Studies for the Acoustic Research Ship C.F.A.V. QUEST

L.J. Leggat, J.T. Ligtelijn, and J.L. Kennedy
Defence Research Establishment Atlantic, Dartmouth (Nova Scotia), Rept. No. DREA-81/2, 30 pp (Aug 1981)
AD-A111 572

Key Words: Ships, Marine propellers, Noise reduction

CFAV QUEST is a specially designed quiet ship used for underwater acoustic research. QUEST was commissioned in 1969; however, advances in sonar technology since that time required additional silencing of the ship propellers. As a result, a propeller design and model test program was undertaken. The shortcomings of the present propellers are described and a comparison is given each model and full scale propulsion results. The design criteria and techniques used for a new set of propellers are reviewed, the suitability of the new propellers is assessed in relation to propulsion and cavitation criteria. Further, the effect on propeller performance and cavitation of modifying the shaft support from a bossing to an A-bracket is examined.

82-2098
LNG Carrier Underwater Noise Study for Baffin Bay

L.J. Leggat, H.M. Merklinger, and J.L. Kennedy
Defence Research Establishment Atlantic, Dartmouth (Nova Scotia), Rept. No. DREA-81/3, 30 pp (Oct 1981)
AD-A111 569

Key Words: Ships, Cargo ships, Underwater sound

Large powerful liquid natural gas carriers may soon ply Arctic waters year round. Concern has been expressed over the impact the resulting noise will have on Arctic marine life. This study includes estimates on LNG carrier radiated noise source levels and resulting sound levels at a given distance from the ship for a number of operating conditions. Measurements of sound propagation and ambient noise conditions in Baffin Bay are used to estimate the ship noise levels in relation to the summertime noise background.

82-2099
Statistical Description of Wave Induced Vibratory Stresses in Ships

S. Gran
Norske Veritas, Oslo, Norway, Rept. No. USCG-M-2-81, 146 pp (Dec 1980)
AD-A111 186

Key Words: Ships, Wave forces, Statistical analysis

This report contains general, theoretical considerations of two peak response spectra with particular attention to wave induced bending and springing stresses in ships. Relationships between periods, RMS values and spectral width are discussed. Different representations of the resulting extreme value under stationary conditions are considered. An approach to the long term description and prediction of extreme stresses has been developed, and has in part been compared with alternative methods. Empirical data related to the theoretical deductions are attached in an appendix.

AIRCRAFT

(Also see Nos. 2069, 2214, 2237)

82-2100

Aircraft Noise -- Takeoff Flight Procedures and Future Goals

K. McK. Eldred

Bolt, Beranek and Newman, Inc., Cambridge, MA, Rept. No. 4662R, EPA-550/9-81-324, 117 pp (Nov 1980)

PB82-170457

Key Words: Aircraft noise, Takeoff

The study was designed to develop and analyze an aircraft takeoff noise data base consisting of areas and populations, computed as a function of noise level, aircraft type, weight and takeoff flight procedure. Six aircraft, each at typical and maximum weight, were chosen to represent the range of civil transport aircraft and engine types. Six types of takeoff flight procedures were selected, three involving cleanup of flaps and leading edge devices before thrust cutback, and three involving thrust cutback before or during cleanup.

82-2101

Evaluation and Abatement of Noise from Aircraft Auxiliary Power Units and Airport Ground Power Units

M.A. Staiano, R.A. Samis, and S. Toth

ORI, Inc., Silver Spring, MD, Rept. No. ORI/TR-1499, EPA-550/9-81-322, 100 pp (Oct 7, 1980)

PB82-168360

Key Words: Aircraft noise, Airports, Noise reduction

APUs and GPUs provide essential service to aircraft during ground operations. Sound levels near these devices range from 80 to 87 dBA at 30 m for APUs, 83 to 103 dBA at 10 m for turbine-engined GPUs, and 71 to 80 dBA at 10 m for piston-engined GPUs. Procedures are provided for: estimating community sound levels due to APUs and GPUs, estimating their exposures in terms of day-night sound levels, and assessing the desirability of noise abatement by comparison to recommended levels for acceptability. Noise abatement options include: operational changes, equipment movement, equipment substitution, equipment quieting, and sound barrier usage.

82-2102

Flight Flutter Test and Data Analysis Techniques Applied to a Drone Aircraft

R.M. Bennett and I. Abel

NASA Langley Res. Ctr., Hampton, VA, J. Aircraft, 19 (7), pp 589-595 (July 1982) 14 figs, 1 table, 12 refs

Key Words: Aircraft, Flutter, Vibration control, Active flutter control, Frequencies, Damping, Time domain method

Modal identification results are presented that were obtained from recent flight flutter tests of a drone vehicle with a research wing called the DAST ARW-1 (for drones for aerodynamic and structural testing, aeroelastic research wing-1). This vehicle is equipped with an active flutter suppression system (FSS). Frequency and damping of several modes are determined by a time-domain modal analysis of the impulse response function obtained by Fourier transformations of data from fast-swept sine wave excitation by the FSS control surfaces on the wing. Flutter points are determined for two different altitudes with the FSS off. Data are given for near the flutter boundary with the FSS on.

82-2103

Subcritical Flutter Testing Using the Feedback System Approach

C.D. Turner

Mech. and Aerospace Engrg. Dept., North Carolina State Univ., P.O. Box 5246, Raleigh, NC 27650, Shock Vib. Bull. 52, Part 3, pp 145-157 (May 1982) 10 figs, 18 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Aircraft, Flutter, Vibration prediction

Current experimental flutter data analysis techniques assume an open-loop system for the aerodynamic and structural model. Frequency, damping, and modal energy are obtained from the experimentally obtained open-loop transfer function. These quantities are used directly or with other analytical methods to predict the critical flutter speed, or for use in subcritical analytical/experimental data comparisons. History has shown that the various techniques and methods are not always reliable. This paper presents an additional technique that represents the aerodynamic and structural model as a closed-loop or feedback system. The feedback system approach is compatible with most current techniques, with the only additional data requirement being the zero air speed transfer function which is obtained during the ground vibration test. In using this approach, two additional parameters are obtained for use in the prediction of the critical flutter speed or for subcritical data comparison.

82-2104

Effect of Store Aerodynamics on Wing/Store Flutter

C.D. Turner

North Carolina State Univ., Raleigh, NC, J. Aircraft, 19 (7), pp 574-580 (July 1982) 6 figs, 3 tables, 25 refs

Key Words: Aircraft wings, Wing stores, Flutter

Owing to the high cost of flutter analysis for aircraft carrying large numbers and types of stores, it is not economically feasible to include store aerodynamics when there will be little change in the flutter results. However, store aerodynamics should be included if it will change the results of the flutter analysis. This study represents the first systematic analytical study of the effect of store aerodynamics on wing/store flutter. A large number of wing/store single carriage configurations and parameters are included in the study; multivariate analysis techniques were used for the first time to analyze wing/store configurations, modal data, and flutter results. The results of the multivariate analysis indicate that it may not be possible to develop general guidelines, but it is possible to develop specific guidelines for use with a particular aircraft.

82-2105

A Wind Tunnel Study of the Flutter Characteristics of a Supercritical Wing

R. Houwink, A.N. Kraan, and R.J. Zwaan

Natl. Aerospace Lab., Amsterdam, The Netherlands, Rept. No. NLR-MP-81002-U, 10 pp (Jan 28, 1981) N82-17129

Key Words: Aircraft wings, Flutter, Wind tunnel testing

A wind-tunnel test on a supercritical wing model is described. Objectives of the test were to investigate the transonic dip and to enable comparison with calculated flutter characteristics in which a quasi-three dimensional transonic theory was used. The beginning of a transonic dip was measured and a satisfactory agreement with theory could be found. An additional flutter instability in the bottom of the transonic dip could be correlated with the loss of transition strip effectivity at low Reynolds numbers.

82-2106

Some Experimental Investigations on Transonic Flutter Characteristics of Thin Plate Wing Models with Sweptback and Tapered Tips

E. Nakai

Natl. Aerospace Lab., Tokyo, Japan, Rept. No. NAL-TR-682, ISSN-0389-4010, 49 pp (Sept 1981) N82-16050

Key Words: Aircraft wings, Variable cross section, Flutter

Some experimental investigations on transonic flutter characteristics were conducted using thin plate cantilevered wing models with sweptback tapered tips, which were elastically supported at the root, in the NAL 0.6m x 0.6m transonic blowdown wind tunnel for flutter testing in the range of Mach numbers from 0.804 to 1.171. The wing models have the tip planform of sweptback angles of 35 degrees at the leading edge and 30 degrees at 1/4 chord line, and an aspect ratio of 1.017 and a taper ratio of 0.6. It is concluded that the flutter boundaries of the wing models have been obtained and the boundaries expressed by the experimental flutter speed coefficient are characterized as having minimum values at around Mach number 1.0. It is also concluded that the considerable increase in the flutter instability area is caused by the decrease in the stiffness of the elastic support at the root of the model.

82-2107

YC-15 Externally Blown Flap Noise

L.G. Peck

Flight Dynamics Lab., AF Wright Aeronautical Labs., Wright-Patterson AFB, OH, Shock Vib. Bull. 52, Part 3, pp 101-113 (May 1982) 17 figs, 5 tables, 9 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Aircraft wings, Acoustic excitation, Fatigue life

The purpose of this project is to determine the acoustic environment on the wing/flap region of the McDonnell-

Douglas YC-15 short takeoff and landing cargo aircraft. The YC-15 is designed for augmented lift through the use of externally blown flaps deflecting the jet exhaust, thereby turning the flow and increasing lift. This process creates an intense acoustic environment on the wing/flap region. Ten transducers on the right inboard wing/flap were selected for data analysis. Test conditions included takeoff, landing, taxi, cruise and ground static over the full range of operating conditions. Results of the test are in the form of narrowband and one-third octave plots, comparing the effects of engine pressure ratio, flap angle, microphone location, and forward speed on the acoustic environment in the wing/flap region.

82-2108

Noise of the SR-3 Propeller Model at 2 Deg and 4 Deg Angle of Attack

J.H. Dittmar and R.J. Jeracki

NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. NASA-TM-82738, E-1051, 30 pp (Dec 1981) N82-16808

Key Words: Propellers, Noise generation

The noise effect of operating supersonic tip speed propellers at angle of attack with respect to the incoming flow was determined. Increases in the maximum blade passage noise were observed for the propeller operating at angle of attack. The noise increase was not symmetrical with one wall of the wind tunnel having significantly more noise increase than the other wall. This was apparently the result of the rotational direction of the propeller.

82-2109

A Shock Wave Approach to the Noise of Supersonic Propellers

J.H. Dittmar and E.J. Rice

NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. NASA-TM-82752, E-1068, 19 pp (Dec 1981) N82-16809

Key Words: Propellers, Noise prediction, Shock wave propagation, Aircraft, Supersonic aircraft

To model propeller noise expected for a turboprop aircraft, the pressure ratio across the shock at the propeller tip was calculated and compared with noise data from three propellers. At helical tip Mach numbers over 1.0, using only the tip shock wave, the model gave a fairly good prediction of the noise for a bladed propeller and for a propeller swept for aerodynamic purposes. In general, the good agreement indicates that shock theory is a viable method for predicting the noise from these supersonic propellers but that the shock strengths from all of the blade sections need to be properly included.

82-2110

Determination of the Dynamic Environment of the F/FB-111 Tail Pod Assembly

J. Chinn and P. Bolds

Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH, Shock Vib. Bull. 52, Part 3, pp 115-129 (May 1982) 30 figs, 3 tables, 3 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Aircraft vibration, Airborne equipment response

A comprehensive dynamic study was conducted on the F/FB-111 aircraft. The vibration and acoustic data were needed to define the environment of the tail pod assembly in order to mount sensitive electronic equipments within. These data were compared with predicted F-111 Tail Warning Systems Specification ASD/ENAM-78-1 and Military Standard Environment Test Methods, 810-C. From the analysis of the data presented in this study, vibration data in the 300 to 500 Hz range exceeded the specification and does not allow a sufficient cushion for endurance testing for many of the transient conditions.

82-2111

An Evaluation of Helicopter Noise and Vibration Ride Qualities Criteria

C.E. Hammond, D.D. Hollenbaugh, S.A. Clevenson, and J.D. Leatherwood

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-83251, 14 pp (Dec 1981) N82-17871

Key Words: Helicopter noise, Helicopter vibration, Noise measurement, Vibration measurement

Two methods of quantifying helicopter ride quality -- absorbed power for vibration only and the NASA ride comfort model for both noise and vibration -- are discussed. Noise and vibration measurements were obtained on five operational US Army helicopters. The data were converted to both absorbed power and DISC's (discomfort units used in the NASA model) for specific helicopter flight conditions. Both models indicate considerable variation in ride quality between the five helicopters and between flight conditions within each helicopter.

82-2112

An Assessment of the A-10's Capability to Operate on Rough Surfaces

T.G. Gerardi and D.L. Morris

Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH, Shock Vib. Bull. 52, Part 3, pp 131-143 (May 1982) 18 figs, 1 table, 2 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Aircraft, Airports, Surface roughness

A study has been conducted on the A-10's capability to operate on rough surfaces; specifically rapidly repaired bomb damaged runways and taxiways. Emphasis was placed on a European combat configured takeoff gross weight of 40,755 pounds and a typical landing configuration weight of 30,300 pounds. Five types of bomb damage repairs were considered, specifically A through E category repairs. Results of the study indicate that the A-10 tends to respond to rough surfaces in its rigid body pitch mode thus making the nose landing gear the critical component.

82-2113

Tomahawk Cruise Missile Flight Environmental Measurement Program

E.S. Rosenbaum and F.L. Gloyna

Convair Div. of General Dynamics Corp., Shock Vib. Bull. 52, Part 3, pp 159-228 (May 1982) 128 figs, 3 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Missiles, Cruisers, Flight tests, Experimental test data, Vibration measurement

This paper presents a summary of vibration measurements made during the systems integration and design validation phases of the Tomahawk cruise missile program. Data is also presented for the ground launched, sea launched, and air launched variants, in both power spectral density and shock spectra formats.

MISSILES AND SPACECRAFT

(Also see No. 2193)

82-2114

A Technique Combining Heating and Impact for Testing Reentry Vehicle Impact Fuzes at High Velocities

R.A. Benham

Sandia Natl. Labs., Albuquerque, NM, Shock Vib. Bull. 52, Part 3, pp 53-63 (May 1982) 18 figs, 10 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Reentry vehicles, Weapons systems, Fuzes (ordnance), Testing techniques

A laboratory testing technique has been developed for simulating the combined reentry aerothermal heating and high velocity impact effects on a ballistic missile warhead contact fuze system. This method consists of subjecting a stationary, instrumented nose tip to the flame of an aluminum powder-liquid oxygen torch system just prior to impact by an explosively propelled aluminum flyer plate target. This turnaround technique (the target moves to strike the stationary nose tip) has been used in the development of several advanced fuzing system designs. This paper describes the testing method and presents results from recent tests.

82-2115

Analysis and Testing of a Nonlinear Missile and Canister System

R.G. Benson, A.C. Deerhake, and G.C. McKinnis

General Dynamics Convair Div., San Diego, CA, Shock Vib. Bull. 52, Part 3, pp 77-87 (May 1982) 21 figs, 2 tables, 3 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Missiles, Protective shields, Rattle space, Vibration response

Analyses and tests were performed to evaluate the nonlinear vibration response of a missile in its protective canister. A diametric rattle space exists between the missile and the canister liner, an elastomer with load deflection properties that are approximately exponential. Simplified MSC/NASTRAN transient response analyses predict the response to be a series of repeated shocks with peak amplitudes that exceed some component allowables. A full-scale vibration test of this configuration showed that the predicted response character is correct but that the amplitude is conservative.

82-2116

SLV-3 Flight Vibration Environment

S.A. Palaniswami, G. Muthuraman, and P. Balachandran

Aerospace Structures Div., Vikram Sarabhai Space Centre, Trivandrum, India, Shock Vib. Bull. 52, Part 3, pp 249-263 (May 1982) 33 figs, 4 tables, 2 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Launchers, Vibration measurement

The vibration test levels for SLV-3, a four stage satellite launch vehicle, was predicted based on empherical method. Second experimental flight of SLV-3 was instrumented at various locations to obtain actual vibration environment. Measurement scheme and data reduction are described. The various causes for the vibration are discussed in detail. The reduced levels from flight data are compared with predicted values.

82-2117

Natural Modes and Real Modal Variables for Flexible Spacecraft

F.R. Vigneron

Communications Research Centre, Ottawa, Ontario, Canada, Rept. No. CRC-1348, 23 pp (Nov 1981) N82-16146

Key Words: Spacecraft, Natural frequencies, Normal modes

A natural model transformation theory which is applicable to flexible spacecraft with damping and gyroscopic forces is described. The theory is arranged into a form which is a generalization of the classical normal modes transformation theory. Modal differential equations are given in terms of real-value scalars. Block diagrams in the time and Laplace transform domains demonstrate the feed-forward and second-order filter characteristics of the structure of the equations. Results for a single-axis flexible dynamics example are compared with earlier published results to show the correlation with the classical normal modes transformation theory.

82-2118

On the Free Vibration Analysis of Spinning Structures by Using Discrete or Distributed Mass Models

W.H. Wittrick and F.W. Williams

Dept. of Civil Engrg., Univ. of Birmingham, Birmingham B15 2TT, UK, J. Sound Vib., 82 (1), pp 1-15 (May 8, 1982) 2 figs, 19 refs

Key Words: Rotating structures, Natural frequencies, Mode shapes, Lumped parameter method, Continuous parameter method, Spacecraft

The analysis of the natural frequencies and modes of vibration of a spinning structure is in general complicated by the presence of gyroscopic, or Coriolis, forces, leading to a complex Hermitian dynamic stiffness (or impedance) matrix. It is shown that if the analysis is performed by using a discrete model with N degrees of freedom, the leading principal minors of the Nth order dynamic stiffness matrix exhibit a type of Sturm sequence property. This leads to a theorem which can be used for the systematic calculation of the natural frequencies of either a discrete system which is assembled from sub-structures, or an assembly of distributed mass members. In both of these cases the order n of the matrix is less than the number of degrees of freedom, and its determinant possesses poles as well as zeros. The application of the theorem to a spinning two-dimensional frame, with distributed mass members, is discussed in some detail.

82-2119

Unsteady Environments and Responses of the Shuttle Combined Loads Orbiter Test

P.H. Schuetz, L.D. Pinson, and H.T. Thornton, Jr.

Rockwell International, Downey, CA, Shock Vib. Bull. 52, Part 2, pp 157-163 (May 1982) 16 figs, 3 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Vibration tests, Wind tunnel testing, Shakers

Both separate and combined wind tunnel and vibration shaker tests were conducted on two structural panels representative of the shuttle orbiter in an 8-foot transonic pressure tunnel to determine the effects of combined loads on the thermal protection system (TPS). The primary objective of this test was to provide a combined full-scale load environment and realistic time history of the dynamic pressures, Mach numbers (through transonic), and dynamic structural responses of these panels. The panels were selected from orbiter locations where interactive load sources such as aerodynamic shock waves, turbulent boundary layers, strut-induced vorticity, and substrate deformation combined to provide high bonding loads between the TPS and the orbiter structure.

82-2120
Vibration M[illegible] of the Space Shuttle Main Engines
E.W. Larson [illegible] Mogil
Rocketdyne Div., Rockwell International, Canoga Park, CA, Shock Vib. Bull. 52, Part 2, pp 165-176 (May 1982) 21 figs, 5 tables (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Vibration tests, Vibration prediction, Design techniques

This paper is a review of the development of the space shuttle main engine zonal vibration criteria, laboratory vibration tests using zonal criteria to verify life of engine components, and the resolution of unexpected structural problems in turbine blades and in the main injector liquid oxygen post due to hot-gas flow. Hardware modifications were made to resist the dynamic loads associated with the vibration environments and the hot-gas flow phenomena until long lead time redesigns could be incorporated. This experience and knowledge will add to the data base of information useful to the design of future liquid rocket engines.

82-2121
Structural Characteristics of the Shuttle Orbiter Ceramic Thermal Protection System
P.A. Cooper
NASA Langley Res. Ctr., Hampton, VA, Shock Vib. Bull. 52, Part 2, pp 101-110 (May 1982) 18 figs, 3 tables, 19 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Heat shields, Ceramics

The ceramic Thermal Protection System (TPS) consists of ceramic tiles bonded to felt pads which are in turn bonded to the Orbiter substructure to protect the aluminum substructure from the heat of reentry. This paper describes the TPS and addresses the results of some of the experimental work including dynamic response studies performed in support of the efforts to certify the TPS for flight.

82-2122
Shuttle Tile Environments and Loads
R.J. Muraca
NASA Langley Res. Ctr., Hampton, VA, Shock Vib. Bull. 52, Part 2, pp 111-125 (May 1982) 18 figs, 7 tables, 4 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Heat shields, Testing techniques

This paper discusses the shuttle tile ascent environments and outlines the procedures used to convert these environments into tile loads. Testing which was performed to quantify or verify the loads is also discussed, along with the load combination rationale which was used. The discussion of the ascent environment is limited to the transonic/supersonic portion of the mission since mechanical design loads occur during this time, and to specific regions of the vehicle, in particular those regions in which undensified critical (black) tiles are located.

82-2123
Dynamic and Static Modeling of the Shuttle Orbiter's Thermal Protection System
J.M. Housner, G.L. Giles, and M. Vallas
NASA Langley Res. Ctr., Hampton, VA, Shock Vib. Bull. 52, Part 2, pp 127-145 (May 1982) 16 figs, 17 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Heat shields, Mathematical models, Ceramics, Tiles, Periodic excitation, Random excitation

This paper describes the dynamic and static analysis methods used to model the nonlinear structural behavior of the shuttle Orbiter's tile/pad thermal protection system. The structural evaluation of the tile/pad system is complicated by the nonlinear stiffening, hysteresis and viscosity exhibited by the pad material. Application of the analysis to square tiles subject to sinusoidal and random excitation is presented along with appropriate test data and correlation is considered good. In order to treat the stress analysis of thousands of individual tiles a nonlinear static analysis was developed which utilizes equivalent static loads derived from the dynamic environment. Using a developed automated data management/analysis system the critical tensile stress at the bondline is examined in thousands of unique tiles in a timely, reliable and efficient manner.

82-2124
Buffet Loads on Shuttle Thermal-Protection-System Tiles
C.F. Coe

NASA Ames Res. Ctr., Moffett Field, CA, Shock Vib. Bull. 52, Part 2, pp 147-155 (May 1982) 15 figs, 1 table (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Heat shields, Tiles

This paper presents results of wind-tunnel and acoustic tests to investigate buffet loads on shuttle thermal-protection-system (TPS) tiles. It also describes the application of these results to the prediction of tile buffet loads for the first shuttle flight into orbit (STS-1). The wind-tunnel tests of tiles were conducted at transonic and supersonic Mach numbers simulating flow regions on the Orbiter where shock waves and boundary-layer separations occur. The acoustic tests were conducted in a progressive wave tube at an overall sound pressure level (OASPL) approximately equal to the maximum OASPL measured during the wind-tunnel tests in a region of flow separation. The STS-1 buffet load predictions yielded peak tile stresses due to buffeting that were as much as 20 percent of the total stress for the design-load case when a shock wave was on a tile.

82-2125

Investigation of Side Force Oscillations during Static Firing of the Space Shuttle Solid Rocket Motor

M.A. Behring

Wasatch Div., Thiokol Corp., Brigham City, UT, Shock Vib. Bull. 52, Part 2, pp 35-41 (May 1982) 12 figs, 3 tables, 3 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Booster rockets, Space shuttles, Forcing function, Low frequencies

Low frequency oscillations in measured side forces have occurred during static testing of the space shuttle solid rocket motor. An investigation was undertaken to define a forcing function to simulate the effect of these oscillations in vehicle loads studies. This paper summarizes data analyses and analytical studies conducted during this investigation.

82-2126

Space Shuttle Solid Rocket Booster Reentry and Decelerator System Loads and Dynamics

R. Moog and D. Kross

Martin Marietta/Denver Div., Denver, CO, Shock Vib. Bull. 52, Part 2, pp 27-33 (May 1982) 8 figs, 2 tables (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Booster rockets, Space shuttles

Recovery of the space shuttle solid rocket boosters required development of a heavy duty large decelerator subsystem. Successful recovery of the first launch pair of boosters demonstrated the adequacy of the design. Flight data consisting of accelerometers and parachute attach point loads provide a basis for evaluation of the decelerator subsystem performance. These results are summarized and compared to preflight predictions.

82-2127

Development of an Automated Processing and Screening System for the Space Shuttle Orbiter Flight Test Data

D.K. McCutchen, J.F. Brose, and W.E. Palm

NASA Lyndon B. Johnson Space Ctr., Houston, TX, Shock Vib. Bull. 52, Part 2, pp 43-51 (May 1982) 16 figs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Flight test data, Data processing

One nemesis of the structural dynamist is the tedious task of reviewing large quantities of data. This data, obtained from various types of instrumentation, may be represented by oscillogram records, root-mean-squared (rms) time histories, power spectral densities, shock spectra, 1/3 octave band analyses, and various statistical distributions. In an attempt to reduce the laborious task of manually reviewing all of the space shuttle orbiter wideband frequency-modulated (FM) analog data, an automated processing system was developed to perform the screening process based upon predefined or predicted threshold criteria.

82-2128

Development of a Vibroacoustic Data Base Management and Prediction System for Payloads

F.J. On and W. Hendricks

NASA Goddard Space Flight Ctr. Greenbelt, MD, Shock Vib. Bull. 52, Part 2, pp 53-64 (May 1982) 6 figs, 2 tables, 2 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Computer programs, Environment simulation, Prediction techniques

A data base management and prediction system called Vibroacoustic Payload Environment Prediction System (VAPEPS) has been developed to serve as a repository for shuttle or expendable booster payload component flight and ground test data. This system is to be made available to the aerospace community for multiple uses including that of establishing the vibroacoustic environment for new payload components. VAPEPS data includes that spectral information normally processed from vibration and acoustic measurements (e.g., power spectra, sound pressure level spectra, etc.).

82-2129

Automation of Vibroacoustic Data Bank for Random Vibration Criteria Development

R.C. Ferebee

Marshall Space Flight Ctr., Huntsville, AL, Shock Vib. Bull. 52, Part 2, pp 65-70 (May 1982) 7 figs, 2 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Vibration measurement, Acoustic measurement, Experimental test data, Data processing, Vibration tests, Acoustic tests

A computerized data bank system has been developed for utilization of large amounts of vibration and acoustic data to formulate component random vibration design and test criteria. This system consists of a computer, graphics tablet, and a dry-silver hard copier which are all desk-top type hardware and occupy minimal space. The vibration and acoustic data are stored in the form of power spectral density and one-third octave band plots over the frequency range from 20 to 2000 Hz. The data was stored by digitizing each spectral plot by tracing with the graphics tablet. The digitized data was statistically analyzed and the resulting 97.5% probability levels were stored on tape along with the appropriate structural parameters. Standard extrapolation procedures were programmed for prediction of component random vibration test criteria for new launch vehicle and payload configurations. This automated vibroacoustic data bank system greatly enhances the speed and accuracy of formulating vibration test criteria.

82-2130

The Developments and Verification of Shuttle Orbiter Random Vibration Test Requirements

M.C. Coody, H.K. Pratt, and D.E. Newbrough

NASA Johnson Space Ctr., Houston, TX, Shock Vib. Bull. 52, Part 2, pp 71-80 (May 1982) 21 figs, 10 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Random vibration, Vibration tests

The unique space shuttle vehicle size, weight, and configuration have given rise to problems in determining vibration requirements and in verifying structural integrity for anticipated mission environments. The application of large-scale vibration testing has played a prominent part in qualifying the shuttle for its intended missions. Severe vibration excitation from rocket engines, aerodynamic noise, and onboard equipment are expected on each shuttle flight. Scale-model wind tunnel and rocket firing tests, as well as full-size rocket engine tests were relied on to define the random forcing functions. The determination of structural response to these environments is described herein, as well as evaluations of measured flight data and comparison with predicted design and test criteria.

82-2131

Space Shuttle Orbiter Acoustic Fatigue Certification Testing

R.A. Stevens

Rockwell International, Downey, CA, Shock Vib. Bull. 52, Part 2, pp 81-99 (May 1982) 31 figs, 1 table, 27 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Acoustic fatigue, Flight test data

The space shuttle orbiter is designed to accommodate a unique combination of loads and environments not previously encountered inasmuch as the reusable vehicle is launched vertically and lands horizontally. The orbiter is subjected to structural vibration caused by engine exhaust-generated acoustic noise during liftoff and aerodynamic noise during atmospheric flight. It was necessary to certify the orbiter structure, thermal protection system (TPS), mechanisms, and equipment, and to gather empirical data to support fatigue analyses and to update vibration and internal noise criteria before the completion of the orbiter flight test (OFT) program. The requirement has largely been satisfied by the partial completion of a comprehensive acoustic fatigue development and certification test program. This paper addresses the certification portion of the program supporting OFT, including test article selection, objectives, environments, results, and conclusions. Also included are comparisons of ground and flight test data.

82-2132

Structural Response to the SSME Fuel Feedline to Unsteady Shock Oscillations

E.W. Larson, G.H. Ratekin, and G.M. O'Connor
Rocketdyne Div., Rockwell International, Canoga Park, CA, Shock Vib. Bull. 52, Part 2, pp 177-182 (May 1982) 16 figs, 4 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Startup response

The space shuttle main engine flight nozzle experiences unexpectedly large accelerations during engine start and cutoff transients. Two fuel feedline failures occurred during separate engine tests. To define the forcing function causing high nozzle accelerations, experimental air flow tests using a subscale model were performed with high-frequency pressure instrumentation such that pressure oscillation amplitude, frequency, and spacial characteristics could be determined. The test results led to the conclusion that the SSME was experiencing pressure oscillations at 38 psi at a frequency of approximately 100 Hz occurring over the last 3 feet of the nozzle. Results of this investigation yielded an understanding of the cause of the failures and led to a redesign that exceeds life requirements.

82-2133

Space Shuttle Solid Rocket Booster Water Entry Cavity Collapse Loads

R.T. Keefe, E.A. Rawls, and D.A. Kross
Chrysler Corp., Slidell, LA, Shock Vib. Bull. 52, Part 2, pp 21-26 (May 1982) 10 figs, 2 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Booster rockets, Landing, Impact shock

SRB cavity collapse flight measurements included external pressures on the motor case and aft skirt, internal motor case pressures, accelerometers located in the forward skirt, mid-body area, and aft skirt, as well as strain gages located on the skin of the motor case. This flight data yielded applied pressure longitudinal and circumferential distributions which compare well with model test predictions. The internal motor case ullage pressure, which is below atmospheric due to the rapid cooling of the hot internal gas, was more severe (lower) than anticipated due to the ullage gas being hotter than predicted. The structural dynamic response characteristics were as expected. Structural ring and wall damage are detailed and are considered to be attributable to the direct application of cavity collapse pressure combined with the structurally destabilizing, low internal motor case pressure.

82-2134

Space Shuttle Main Engine (SSME) Pogo Testing and Results

J.R. Fenwick, J.H. Jones, and R.E. Jewell
Rocketdyne Div., Rockwell International, Canoga Park, CA, Shock Vib. Bull. 52, Part 2, pp 1-20 (May 1982) 29 figs, 21 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Flutter, Pogo effect

To effectively assess the pogo stability of the space shuttle vehicle, it was necessary to characterize the structural, propellant, and propulsion dynamics subsystems. Extensive analyses and comprehensive testing programs were established early in the project as an implementation of management philosophy of pogo prevention for space shuttle. This paper discusses the role of the space shuttle main engine in the pogo prevention plans, compares the results obtained from engine ground testing with analysis, and presents measured data from STS-1 flight.

82-2135

Test Program to Develop Vibroacoustics Test Criteria for the Galileo Bus

D.L. Kern and C.D. Hayes
Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, Shock Vib. Bull. 52, Part 3, pp 229-247 (May 1982) 2 tables, 30 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Space shuttles, Vibration tests, Acoustic tests, Testing techniques

The Galileo spacecraft, to be launched on shuttle wide body centaur, must be able to withstand random vibrations induced by the acoustic noise environment inside the shuttle

payload bay during liftoff and transonic/max Q events. In order to define random vibration test requirements for Galileo bus-mounted hardware, an extensive vibroacoustics test program was conducted on hardware available from the previous Voyager spacecraft development program. The Galileo test program consisted of acoustic tests on three configurations of the Voyager dynamic test model bus and shaker random vibration tests on two flight-like bus equipment bay assemblies and one dummy equipment bay assembly. The primary goal of the acoustic tests was to define vibration levels at locations on the bus structure representative of inputs to bus equipment bay assemblies and to obtain response data on bus bay subassemblies for correlation with the vibration tests response data. The primary purpose of the vibration tests was to determine if the vibration tests excited subassembly responses at least as severely as the bus acoustic tests.

BIOLOGICAL SYSTEMS

HUMAN

82-2136

Comparing the Relationships between Noise Level and Annoyance in Different Surveys: A Railway Noise vs. Aircraft and Road Traffic Comparison

J.M. Fields and J.G. Walker
Inst. of Sound and Vib. Res., Univ. of Southampton, Southampton S09 5NH, UK, J. Sound Vib., 81 (1), pp 51-80 (Mar 8, 1982) 7 figs, 5 tables, 24 refs

Key Words: Railroad trains, Traffic noise, Aircraft noise, Motor vehicle noise, Noise tolerance, Human response

Annoyance expressed in a railway noise survey is compared with that in two road traffic and three aircraft surveys in order to determine whether responses to various environmental noises are similar or are source-specific. Railway noise is less annoying than other noises at any given high noise level. Railway noise annoyance increases less rapidly with increasing noise level. At high noise levels this gap in reactions averages about 10 dB but ranges from 4 dB to more than 20 dB. Comparisons between the findings in the different surveys can be made only after considering differences in noise index calculation procedures, human response measurement procedures and annoyance moderating conditions. The methodology for comparing surveys is examined. It is found that methodological uncertainties lead to imprecise comparisons and that different annoyance scales give different estimates of intersurvey differences.

82-2137

A Comparison of Models to Predict Annoyance Reactions to Noise from Mixed Sources

S.M. Taylor
Dept. of Geography, McMaster Univ., Hamilton, Ontario, Canada, J. Sound Vib., 81 (1), pp 123-128 (Mar 8, 1982) 1 fig, 6 tables, 25 refs

Key Words: Traffic noise, Aircraft noise, Human response

Many residential communities are exposed to environmental noise from a mixture of sources. A simple energy summation model provides a convenient method for predicting annoyance reactions in mixed source situations but there is research evidence that the validity of its application is questionable. In this paper various alternative models are discussed. Their predictive powers are compared by using noise and social survey data collected at residential sites in the vicinity of Toronto International Airport. Sites were purposely selected to represent a range of aircraft and road traffic noise combinations. The implications of the results for predicting annoyance reactions to mixed sources are considered.

82-2138

Vibration Nuisance from Road Traffic at Fourteen Residential Sites

C.J. Baughan and D.J. Martin
Transport and Road Res. Lab., Crowthorne, UK, Rept. No. TRRL-LR-1020, 35 pp (1981)
PB82-174764

Key Words: Traffic-induced vibrations, Traffic noise, Human response

This report describes a combined social and physical measurement survey which investigated the traffic vibration nuisance experienced by people in residential roads. Interviews with residents, and measurements of noise and traffic were carried out at 14 sites in London. The relations between the physical parameters of traffic and traffic noise and the degree of vibration nuisance experienced by residents were investigated in order to derive a physical index which provided a reasonably good correlation with vibration nuisance. The different forms of nuisance caused by vibration from road traffic were also studied.

82-2139

Vibration Control in Worker Protection and Occupational Hygiene (Aspekte des Arbeitsschutzes und der Arbeitshygiene bei der Schwingungsabwehr)

G. Meltzer

Akademie der Wissenschaften der DDR, Inst. f. Mechanik, Berlin, Germany, Maschinenbautechnik, 31 (5), pp 196-200 (May 1982) 12 figs, 16 refs (In German)

Key Words: Hand tools, Vibration tolerance, Human response, Active vibration control, Vibration isolation

Effects of vibration on health and early signs of occupational diseases caused by vibration are discussed. Based on these findings various means for vibration protection are developed. Of particular importance is e.g., the development of protective gloves for use with vibrating hand tools and active vibration isolation in tractor seats.

82-2140

Development of Artificial Hands for Use in Chain Saw Vibration Measurement

B.-O. Byström, A. Nilsson, and E. Olsson
Dept. of Mech. Engrg., Univ. of Luleå, Luleå S-95187, Sweden, J. Sound Vib., 82 (1), pp 111-117 (May 8, 1982) 8 figs, 6 refs

Key Words: Human hand, Vibration response, Saws, Mathematical models

The dynamic properties of the human hand were measured in the laboratory. The results were compared with those obtained by others and used to test three different hand model ideas. One of these was further developed and designed to fit in a test rig. Measurements were made on chain saws in the rig during cutting and with the chain running free. The results are compared to similar measurements on hand held chain saws. The hand model test results show good agreement with the hand held measurements but have much better repeatability.

82-2141

Bio-Dynamic Response of Human Head during Whole-Body Vibration Conditions

B.K.N. Rao
Dept. of Mech. and Production Engrg., Birmingham Polytechnic, Perry Barr, UK, Shock Vib. Bull. 52, Part 3, pp 89-99 (May 1982) 5 figs, 8 tables, 33 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Head (anatomy), Vibration response

Studies have shown that many commercial and military vehicles transmit high acceleration levels to the occupants in the frequency regions of 1 to 30 Hz, wherein lies the major body resonances. These bodily resonances influence the performance and psychology of drivers and passengers in various ways depending upon the magnitude of vibration input, posture, nature of task, attitude, etc. In the vehicle ride application area, it is now realized that the transmission of these vibrations to the head of occupants may significantly effect their dynamic visual acuity, resulting in tunneling and/or blurring of vision. Very few studies have been cited in the literature concerning the transmission of vibration from feet-to-head, and/or from seat-to-head. Owing to a limited number of subjects employed, limited postures, different facilities and experimental techniques, the results of these studies have been interpreted in different ways. Also, most of the data refers to military personnel and its application to civilian population raises some doubts. Clearly, a need exists for accurate information on the head transmissibility characteristic of the human head, by exposing subjects from the civilian population to low frequency sinusoidal and random vibrations in the frequency range of 1 to 30 Hz. This paper covers the results obtained for various postures and different conditions.

82-2142

Comparison of Human Skull and Spherical Shell Vibrations -- Implications for Head Injury Modeling

T.B. Khalil and D.C. Viano
Biomedical Sci. Dept., General Motors Res. Labs., Warren, MI 48090, J. Sound Vib., 82 (1), pp 95-110 (May 8, 1982) 10 figs, 2 tables, 28 refs

Key Words: Head (anatomy), Shells, Spherical shells, Impact response, Mathematical models

Spherical shell models have been formulated as geometric approximations of the human head. By insuring geometrical and material similarity between the model and human head, impact response and skull fracture studies were expected to yield results in close agreement with model predictions. This, however, was not the case. Model predictions of skull fracture loads were typically twice the observed level. A comparision was made between the resonant frequencies of two dry human skulls and corresponding spherical shell models. Poor agreement was observed. A vibrational analysis of the model revealed that the uniformity of the spherical shell approximately doubles the effective stiffness and resonant frequencies as compared with the dry human skull.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

82-2143
Friction Damped Base Isolation Systems
K.E. Beucke
Univ. of California, Berkeley, 117 pp (1981)
DA8211855

Key Words: Energy absorption, Base isolation, Seismic design, Coulomb friction

The concept of base isolation can be a very effective aseismic design strategy. As it is a low frequency system stringent design response spectra requirements necessitate the inclusion of a displacement control system associated with the base isolation system. The displacement control system adopted in this research is a split foundation sliding friction damping system providing a frictional force that is proportional to the relative displacement between the structure and the ground. A practical base isolation system including a displacement control system is described and tested on the earthquake simulator of the EERC. The experimental results, presented here, indicated the need for an extended model for the damping force. The model adopted is a combination of linear viscous damping, constant Coulomb friction and linear Coulomb friction.

82-2144
Time and Temperature Effects on Cushions
G.S. Mustin
Naval Sea Systems Command, Washington, DC, Shock Vib. Bull. 52, Part 4, pp 131-140 (May 1982) 2 figs, 7 tables, 18 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Packaging materials, Shock absorption, Temperature effects, Time-dependent parameters

Dynamic behavior of cushions can be modeled by exponential equations describing the time and temperature dependent loci of the nadirs of logarithmic parabolas in the acceleration-static stress plane and of the lengths of the latus recta of these parabolas. A set of nine empirical constants is sufficient to describe this dynamic behavior over a wide range of drop heights and thicknesses at temperatures ranging from slightly above the glass temperature of the polymer to 344°K. Recommendations are offered for future work exploiting this finding.

82-2145
Optimum Absorber Parameters for Various Combinations of Response and Excitation Parameters
G.B. Warburton
Dept. of Mech. Engrg., Univ. of Nottingham, Nottingham, UK, Earthquake Engrg. Struc. Dynam., 10 (3), pp 381-401 (May-June 1982) 2 figs, 10 tables, 15 refs

Key Words: Absorbers (equipment), Vibration absorption (equipment), Optimization

In the present paper simple expressions for optimum absorber parameters are derived for undamped one degree-of-freedom main systems for harmonic and white noise random excitations with force and frame acceleration as input and minimization of various response parameters. These expressions can be used to obtain optimum parameters for absorbers attached to complex systems provided that optimization is with respect to an absolute, rather than a relative, quantity. The requirement that the natural frequencies should be well separated is investigated numerically for the different cases. The effect of damping in the main system on optimum absorber parameters is also investigated.

82-2146
Response of Pneumatic Isolator to Standard Pulse Shapes
M.S. Hundal
The Univ. of Vermont, Dept. of Mech. Engrg., Burlington, VT 05405, Shock Vib. Bull. 52, Part 4, pp 161-168 (May 1982) 6 figs, 9 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Shock isolators, Pneumatic isolators

Operation of a symmetric passive pneumatic shock isolator is analyzed. The governing equations are put in dimensionless form and solved numerically. A parametric study is made in terms of dimensionless parameters representing mass, stiffness and orifice/piston area ratio. On the basis of a sustained acceleration input the system is found to have optimum response for a certain range of the area ratio.

System response is determined for six pulse shapes: rectangular, half-sine, versed sine, rising saw-tooth, falling saw-tooth and triangle.

82-2147

Shock-Isolation by Beam-Shaped Equipments Supported by Springs and Dampers (Schockisolierung durch federnd und gedämpft gelagerte Balkenfundamente)

J. Wauer

Institut f. Technische Mechanik, Universität Karlsruhe, Forsch. Ingenieurwesen, 48 (2), pp 55-99 (1982) 3 figs, 8 refs

(In German)

Key Words: Vibration isolation, Time domain method

Vibration isolation is a classical problem of mechanical engineering. In the case of a rigid single-degree-of-freedom equipment it is discussed comprehensively, but for distributed parameter systems under impact loads it is unsolved. By means of a generalized model analysis based on first order systems with reference to time it is shown how transient vibrations of damped one-dimensional continua are described analytically in the time-domain without splitting into discrete parts. .n this way the shock-isolation can be completely estimated.

82-2148

Rubber Isolators for the Adats Missile

J.-P. Frottier and C.S. O'Hearne

Oerlikon-Buehrle Werkzeugmaschinenfabrik, Zurich, Czechoslovakia, Shock Vib. Bull. 52, Part 4, pp 123-130 (May 1982) 22 figs, 1 ref (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Vibration isolators, Elastomers, Mountings, Instrumentation mounts, Tanks (combat vehicles), Gunfire effects

Rubber isolators are not usually used in high performance missiles. Reasons for this are the dearth of rattle space and the difficulties in determining, and hence designing for, the effects of high, steady acceleration. The present case is exceptional: a lightweight item is suspended on a 1000 Hz isolation system. The item is a missile fin-tip mounted photodetector which receives uplink information on a laser beam carrier. The purpose of isolating the detector is to decrease microphonic noise in its output signal. In the development of this system, a piezoelectric shaker operating to 20 KHz was used to measure the isolation. Excitation in a tactical environmental simulation was provided at a test facility and during rocket motor static firings. The ramburner firing produces an acoustical source similar to the ADATS rocket motor plume. Results obtained in an early flight test are also reported.

82-2149

Nonlinear Analysis of Pneumatic Generators Used for Vibration Control

S. Sankar, R.R. Guntur, and S.G. Kalambur

Concordia Univ., Montreal, Quebec, Canada, Shock Vib. Bull. 52, Part 4, pp 87-101 (May 1982) 9 figs, 2 tables, 11 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Pneumatic isolators, Passive isolation, Active isolation

This paper deals with pneumatic isolators using passive and active force generators. Through nonlinear analysis, realistic digital simulation programs have been developed for investigating the transmissibility characteristics of active and passive pneumatic systems. It is shown that active system offers greater flexibility to the designer than the passive system. Based on the results of the study of the active system, guide lines for selecting var!ous feedback gains are presented.

82-2150

Active Vibration Control of Large Flexible Structures

T.T. Soong and J.C.H. Chang

Dept. of Civil Engrg., State Univ. of New York at Buffalo, Amherst Campus, Buffalo, NY 14260, Shock Vib. Bull. 52, Part 4, pp 47-54 (May 1982) 3 figs, 3 tables, 7 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Active vibration control, Spacecraft, Buildings, Bridges

This paper is concerned with active vibration control of large and complex structures. An important problem of actively controlling large flexible structures is one of compensating for control and observation spillover when a large-dimensional system must be controlled by a much smaller dimensional controller. A modal control design procedure is developed which not only insures that the controlled structural modes stay close to the designed values but also preserves stability in the uncontrolled modes. The sensitivity of spillover compensation to the placement of controllers and sensors is also studied.

82-2151

Performance Analysis of High-Speed Hydraulic Suspension Systems in Multiple Wheeled Land Transporters

P. Woods

Martin Marietta Corp., Denver, CO, Shock Vib. Bull. 52, Part 4, pp 73-85 (May 1982) 14 figs, 3 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Suspension systems (vehicles), Hydraulic dampers, Interaction: structure-fluid

Fluid/structure interaction is developed for a hydraulic suspension system. Finite element models of the fluid are developed in a manner identical to structural elements. After imposing continuity, the fluid system is coupled to the structural system by Rayleigh-Ritz assumed modes which satisfy boundary conditions. Damping in the combined system is built up from discrete constant coefficients for the tires, from laminar flow resistance in the fluid and from modal damping assumed for the structure. Input disturbances at the roadway surface are expressed as functions of time or random acceleration spectra. Response of the transporter system is expressed in time or frequency domains. Good agreement is obtained with a limited amount of test data.

TIRES AND WHEELS

82-2152

Some Mechanisms of Excitation of a Railway Wheel

M.L. Munjal and M. Heckl

Dept. of Mech. Engrg., Indian Inst. of Sci., Bangalore 560012, India, J. Sound Vib., 81 (4), pp 477-489 (Apr 22, 1982) 13 figs, 10 refs

Key Words: Wheels, Railway wheels, Interaction: rail-wheel

Railway wheel vibrations are caused by a number of mechanisms. Two of these are considered: gravitational load reaction acting on different points of the wheel rim, as the wheel rolls on, and random fluctuating forces generated at the contact patch by roughness on the mating surfaces of the wheel and rail. The wheel is idealized as a thin ring, and the analysis is limited to a single wheel rolling on a rail. It is shown that the first mechanism results in a stationary pattern of vibration, which would not radiate any sound. The acceleration caused by roughness-excited forces is much higher at higher frequencies, but is of the same order as that caused by load reaction at lower frequencies. The computed acceleration level caused by roughness is comparable with the observed values, and is seen to increase by about 10 dB for a doubling of the wagon speed.

BLADES

82-2153

Reduction of Blade Passage Tone by Angle Modulation

Y.A. Fiagbedzi

Dept. of Mech. Engrg., Univ. of Sci. and Tech., Kumasi, Ghana, J. Sound Vib., 82 (1), pp 119-129 (May 8, 1982) 3 figs, 1 table, 15 refs

Key Words: Blades, Fan blades, Noise reduction

Blade staggering has been used in both centrifugal and axial flow fans to reduce discrete tones. Impeller hub resilience, causing fan torsional oscillations, appears to be equivalent to blade staggering in that both lead to angle modulation of the blade passage sound. By using Jacobi-Anger expansions, the sound reductions resulting from the angle modulation effects of these two equivalent techniques are predicted. Excellent agreement is found with published data.

BEARINGS

(Also see No. 2163)

82-2154

Study on Circular EHD Squeeze Films under Periodic Motion

K. Ikeuchi, H. Mori, T. Okubo, and S. Ichi

Faculty of Engrg., Kyoto Univ., Kyoto, Japan, Bull. JSME, 25 (202), pp 646-652 (Apr 1982) 19 figs, 8 refs

Key Words: Plates, Circular plates, Lubrication, Squeeze-film bearings, Elastomers

In this paper circular squeeze films between a rigid plane and an elastomer attached on a rigid base or a thin circular plate under periodic motion are analyzed, and the film thickness, film pressure, load capacity, and the absorbed power are calculated. In the experiment thrust bearings with two kinds of compliant surfaces are vibrated and the floating height and film pressure are measured to confirm the theory.

82-2155
Two-Dimensional Analysis of Stiffness and Damping Factor of Spiral Groove Spherical Bearing
Y. Miyake, N. Kawabata, A. Tominaga, and S. Murata
Faculty of Engrg., Osaka Univ., 2-1 Yamada-oka, Suita, Osaka, Japan, Bull. JSME, 25 (202), pp 663-670 (Apr 1982) 9 figs, 10 refs

Key Words: Bearings, Thrust bearings, Spherical bearings, Stiffness coefficients, Damping coefficients

A two-dimensional analysis is presented for the dynamic performance of spiral groove spherical thrust bearings. The analysis is carried out to obtain the dynamic stiffness and damping factor for the case of vertical and translatory oscillations and the reaction forces of the film in the case of whirl motion. The analysis is restricted to the case where the centers of the rotating and stationary spheres coincide. New equations based on the narrow groove hypothesis are derived and numerical examples are presented. The results are compared with those of the two-dimensional analysis to demonstrate the accuracy.

82-2156
An Influence of Inertia Forces on Stability of Turbulent Journal Bearings
H. Hashimoto and S. Wada
School of Engrg., Tokai Univ., Hiratsuka-shi, Kanagawa, Japan, Bull. JSME, 25 (202), pp 653-662 (Apr 1982) 10 figs, 13 refs

Key Words: Bearings, Journal bearings, Inertial forces, Stiffness coefficients, Damping coefficients

Turbulence and inertia effects on the static and dynamic characteristics of high speed journal bearings are discussed. Because of the difficulty of analysis, infinitely long and short width bearings are dealt with analytically instead of finite width bearings. It is found that the static characteristics such as the Sommerfeld number and the locus of shaft center are affected mainly by turbulence but the dynamic ones such as the spring, damping and acceleration coefficients of lubricant film and the stability of rotors are affected by inertia.

GEARS

(Also see No. 2212)

82-2157
Theoretical and Experimental Investigation of Static and Dynamic Teeth Forces in Synchronized Drives of Wankel Engines (Theoretische und experimentelle Untersuchung der statischen und dynamischen Zahnkrafte im Synchronisiergetriebe von Wankel-Motoren)
A. Schorpp
Fortschritt-Berichte VDI-Z., Series 11, No. 46, 62 pp (1981) 21 figs, 1 table, 48 refs. Avail: VDI-Verlag GmbH, Postfach 1139, 4000 Dusseldorf 1, Germany (In German)

Key Words: Wankel engines, Gear teeth, Synchronous motors

Forced periodic vibrations of Wankel engines caused by forces in the synchronized drive gear teeth are investigated. In the theoretical investigation of this vibratory system, linear inhomogenous differential equations are derived by means of a mathematical model and tooth forces are calculated. The results are verified by experiment. The results of calculation and of experiment show a clear dependence of tooth forces on speed. At a constant speed the effect of load moment is negligibly small.

82-2158
Bending Strength of Spur Gear Teeth (1st Report, Cumulative Fatigue Damage of Normalized 0.45% Carbon Steel)
T. Tobe and N. Maruyama
Faculty of Engrg., Tohoku Univ., Sendai, Japan, Bull. JSME, 25 (202), pp 671-678 (Apr 1982) 14 figs, 6 tables, 24 refs

Key Words: Gear teeth, Spur gears, Steel, Fatigue tests, Fatigue life

Bending fatigue tests of spur gear teeth made of normalized 0.45% carbon steel (JIS S45C) are performed and several cumulative damage rules are examined taking into account the scatter of fatigue strength. The effect of the pattern of time variation of the tooth fillet stress is also investigated. Program loading tests with variation coefficients 1/12 and

1/9 indicate that Miner's rule is adaptable in the time endurance region. The effect of the pattern of fillet stress on fatigue damage is also observed.

COUPLINGS

(See No. 2257)

FASTENERS

82-2159

Fatigue Resistance of Adhesively Bonded Structural Connections

H. Nara and D. Gasparini

Case Western Reserve Univ., Cleveland, OH, Rept. No. FHWA/OH-81/011, 138 pp (Nov 1981)

PB82-163189

Key Words: Joints (junctions), Adhesives, Fatigue life, Structural members, Bridges

It is known that certain welded details adversely affect the fatigue life of bridge members. The utility and feasibility of steel to steel adhesive bonded connections as substitutes for such details is evaluated. Large scale fatigue tests indicated that adhesives can perform structural functions equal to those of welds without decreasing the fatigue life of beams. Representative adhesive connections on bridges and their performance criteria are broadly defined. Available structural adhesives which satisfy the design criteria are examined. Modified epoxies and acrylics are the structural adhesives most promising for bridge applications. Alternate adhesive constitutive equations and bond strength theories are reviewed.

82-2160

Durability of Adhesive Bonded Structures Subjected to Acoustic Loads

H.F. Wolfe and I. Holehouse

Advisory Group for Aerospace Res. and Dev., Neuilly-sur-Seine, France, Rept. No. AGARD-R-701, 17 pp (Dec 1981)

AD-A111 488

Key Words: Adhesives, Acoustic response, Acoustic fatigue, Composite materials

The development of high strength adhesives, integral damping, advanced composite materials and lower cost manufacturing techniques has led to structural concepts quite different from the conventional riveted configurations. These new structural concepts are finding widespread interest in aircraft design and application and they must survive high intensity acoustic excitation for the service life of the aircraft. Acoustic fatigue prediction information for advanced composite and adhesively bonded structures is rather limited, and since these concepts represent a significant change in dynamic characteristics and failure mechanisms, prediction methods based on riveted technology may not be valid. This report constitutes a review of the potential problem by the SMP and an effort to determine if there was sufficient concern in several NATO countries to warrant further activity.

82-2161

Damping in Structural Joints

C.F. Beards

Dept. of Mech. Engrg., Imperial College of Sci. and Tech., Exhibition Rd., London SW7 2BX, UK, Shock Vib. Dig., 14 (6), pp 9-11 (June 1982) 22 refs

Key Words: Joints (junctions), Vibration damping, Reviews

The inherent damping of fabricated structures can be greatly increased without impairing the integrity of the structure by controlling the clamping forces in joints. Furthermore, the frequencies at which resonance occurs can be controlled. Although some surface damage is inevitable in joints designed to dissipate vibrational energy by relative interfacial slip, special surface preparations can reduce this damage to acceptable levels in most structures. Linearized analyes provide adequate qualitative prediction of the effects of joint damping on the vibrations of a structure.

82-2162

Evaluation of Bonding Parameters on Random Fatigue Life of Bonded Aluminum Joints

H.F. Wolfe, C.L. Rupert, and H.S. Schwartz

Flight Dynamics Lab., AFWAL, Wright-Patterson AFB, OH, J. Aircraft, 19 (7), pp 581-588 (July 1982) 16 figs, 3 tables, 5 refs

Key Words: Joints (junctions), Aluminum, Fatigue life, Fatigue tests

Eighteen adhesively bonded aluminum coupons were tested on a vibration shaker at room temperature to determine the effects of varying the adhesive type/thickness, primer, and adherend surface preparation on their random bending fatigue life. Most of the fatigue failures occurred within 10^6 to 10^7 cycles, all at 900 microstrain. While neither the primer thickness nor the surface treatment seemed to influence the overall results, the coupons with thicker adhesive had a noticeably shorter fatigue life. Fractographic analyses of the failed adhesive surfaces showed the locus of fracture for all coupons was predominantly within the adhesive. The nitrile phenolic adhesive demonstrated a better fatigue resistance than the nitrile epoxy.

LINKAGES

82-2163

Analysis of the Dynamical Behaviour of Spatial Four-Bar Mechanisms (Analyse des dynamischen Verhaltens räumlicher Gelenkvierecke)

H. Bartels and H. Hiller

Inst. A f. Mechanik der Universität Stuttgart, Pfaffenwaldring 9, D-7000 Stuttgart 80, Fed. Rep. Germany, Ing. Arch., 52 (1/2), pp 47-61 (1982) 19 figs, 7 refs (In German)

Key Words: Four bar mechanisms, Hinges, Bearings, Dynamic response

The equations of motion for the general spatial four-bar mechanism which appears in many technical applications, are derived by means of the theorems of momentum and moment of momentum. Thus, the reaction forces in the bearings and the combining hinges can be calculated simultaneously. Furthermore, the dynamical behavior of the four-bar mechanism depends on the technical realization of the hinged articulations. The equations of motion are solved numerically, and the procedure is demonstrated by an example.

SEALS

82-2164

Effect of Seals on Rotor Systems

D.P. Fleming

NASA Lewis Res. Ctr., Cleveland, OH 44135, Shock Vib. Bull. 52, Part 1, pp 55-65 (May 1982) 17 figs, 22 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Seals, Rotors, Stiffness coefficients, Damping coefficients

Seals can exert large forces on rotors. As an example, in turbopump ring seals film stiffness as high as 90 MN/m (500 000 lb/in) have been calculated. This stiffness is comparable to the stiffness of rotor support bearings; thus seals can play an important part in supporting and stabilizing rotor systems. This paper reviews the work that has been done to determine forces generated in ring seals. Working formulas are presented for seal stiffness and damping, and geometries to maximize stiffness are discussed. An example is described where a change in seal design stabilized a previously unstable rotor.

STRUCTURAL COMPONENTS

BARS AND RODS

(Also see No. 2200)

82-2165

Torsional Dispersion Relations of Waves in an Infinitely Long Clad Cylindrical Rod

R. Parnes

Laboratoire de Mécanique des Solides, Ecole Polytechnique, 91128, Palaiseau, France, J. Acoust. Soc. Amer., 71 (6), pp 1347-1351 (June 1982) 4 figs, 6 refs

Key Words: Rods, Wave propagation, Wave guide analysis

The dispersion relations of torsional waves propagating in a system consisting of an elastic rod of radius a embedded in a linear elastic medium are investigated. Phase speeds of waves of wavelength λ which propagate under steady-state conditions are determined. The dispersion relations are found to be dependent on the geometric ratio a/λ, as well as on nondimensional ratios of the rod-medium properties. The frequency equation obtained is analyzed and upper and lower bounds on the phase speed are determined. It is shown that torsional waves can propagate freely only if the propagation speed of torsional waves in the corresponding free rod is less than that of shear waves propagating in the medium. Results are presented by means of dispersion curves and surfaces.

BEAMS

(Also see Nos. 2086, 2172, 2200)

82-2166

Stability of a Pretwisted Tapered Cantilever Beam Subjected to Dissipative and Follower Forces

R.C. Kar and W. Hauger

Inst. f. Mechanik, Technische Hochschule, 6100 Darmstadt, Fed. Rep. Germany, J. Sound Vib., 81 (4), pp 565-573 (Apr 22, 1982) 3 figs, 11 refs

Key Words: Beams, Cantilever beams, Variable cross section, Follower forces, Internal damping, External damping

Stability of a pretwisted tapered cantilever beam of rectangular cross-section subjected to a follower force at its free end is investigated. The effects of internal and external damping are included in the study. The non-self-adjoint boundary value problem is formulated with the Euler-Bernoulli theory and an associated adjoint boundary value problem is introduced. Approximate values of the critical load are calculated on the basis of a suitable adjoint variational principle for several values of the geometric and material parameters of the beam. The results are shown in graphs.

82-2167

An Integral Equation Analysis of the Harmonic Response of Three-Layer Beams

E. Ioannides and P. Grootenhuis

Dept. of Mech. Engrg., Imperial College of Sci. and Tech., London SW7 2BX, UK, J. Sound Vib., 82 (1), pp 63-82 (May 8, 1982) 6 figs, 2 tables, 27 refs

Key Words: Beams, Sandwich structures, Viscoelastic core-containing media, Harmonic response

The integral equations of harmonic motion have been derived and solved for three-layer sandwich beams with a constrained linear viscoelastic core. The method of solution required the construction of the Green's vector for a beam in analytical form. The integral equations were then derived and readily approximated by matrix equations which were solved numerically. The corresponding eigenvalue problem was solved so that the modal frequencies and the beam loss factor could be calculated directly. The integral equation analysis offers a fast and efficient alternative to the traditional methods based on the solution of the differential equations of motion. The method has been verified by comparison with experimental results for three-layer cantilevers and simply supported beams.

82-2168

An Investigation of Dynamic Analysis Methods for Variable-Geometry Structures

F. Austin

Grumman Aerospace Corp., Bethpage, NY, Rept. No. NASA-CR-167498, CSS-SSS-RP002, 280 pp (Dec 1980)

N82-17522

Key Words: Beams, Variable cross section, Dynamic structural analysis, Computer programs

Selected space structure configurations were reviewed in order to define dynamic analysis problems associated with variable geometry. The dynamics of a beam being constructed from a flexible base and the relocation of the completed beam by rotating the remote manipulator system about the shoulder joint were selected. Equations of motion were formulated in physical coordinates for both of these problems, and FORTRAN programs were developed to generate solutions by numerically integrating the equations.

COLUMNS

82-2169

Ductility of Square-Confined Concrete Columns

R. Park, M.J.N. Nigel Priestley, and W.D. Gill

Dept. of Civil Engrg., Univ. of Canterbury, Christchurch, New Zealand, ASCE J. Struc. Div., 108 (4), pp 929-950 (Apr 1982) 12 figs, 3 tables, 20 refs

Key Words: Columns, Concretes, Seismic design, Standards and codes

A brief review showed considerable differences in the quantity of rectangular hoops required by various seismic design codes in the potential plastic hinge regions of rectangular reinforced concrete columns. Tests conducted on four nearly full size reinforced concrete columns with a 550 mm (21.7 in.) square cross section, various axial load levels, and various quantities of rectangular hoops, are described. The columns demonstrated very ductile behavior when loaded by simulated seismic loading up to displacement ductility factors of at least 6, confirming the adequacy of the proposed design provisions.

82-2170

Vertical Seismic Load Effect on Hysteretic Columns

T.-Y. Shih and Y.K. Lin

Nuclear Technology Inc., San Jose, CA, ASCE J. Engrg. Mech. Div., 108 (2), pp 242-254 (Apr 1982) 8 figs, 15 refs

Key Words: Columns, Seismic response

An analytical method is developed to calculate the statistical properties of the response of hysteretic columns under earthquake excitations, with special emphasis on the effect of the vertical ground acceleration. Both the vertical and horizontal ground accelerations are modeled as amplitude-modulated Gaussian random processes, and the restoring force in a column is assumed to follow a functional relationship. Numerical results are presented for two columns, having two contrasting values of the postyielding to preyielding stiffness ratio of 0.5 and 0.1, respectively.

82-2171

Dynamic Buckling of Pinned Columns

J.M. Ready

David W. Taylor Naval Ship R&D Ctr., Bethesda, MD 20084, Shock Vib. Bull. 52, Part 5, pp 59-98 (May 1982) 29 figs, 10 tables, 8 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981 Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Columns, Dynamic buckling, Shipboard equipment response, Underwater explosions

To develop design guidance for foundations of shipboard equipment a series of dynamic tests on parametrically varied pinned columns were conducted. Tests showed that incipient buckling can occur at loads as low as 70 percent of the Euler buckling load. Applied dynamic loads of 50 percent of the Euler load do not appear to cause buckling when eccentricity is low. The tests also showed that columns can carry loads that are multiples of the Euler load provided the load duration is short compared to the fundamental bending period of the columns; otherwise the columns collapse.

82-2172

Cyclic Analysis of Fixed-Ended Steel Beam-Columns

S. Toma and W.F. Chen

Office of Welding Research Lab., Kawasaki Heavy Industries Ltd., Chiba-Prefecture, Japan, ASCE J. Struc. Div., 108 (6), pp 1385-1399 (June 1982) 9 figs, 10 refs

Key Words: Beam-columns, Cyclic loading, Off-shore structures, Drilling platforms

The paper describes an analytical model for theoretically predicting the inelastic cyclic behavior of fixed-ended steel beam-columns subjected to one cycle of axial loading. The analysis is based on the hinge-by-hinge method used widely in the study of elastic-plastic behavior of steel structures. In this analysis, the solution of an elastic-plastic beam-column under cyclic and reversed loading is obtained as a sequence of elastic column solutions which follow the history of loading. Using this analytical procedure, closed form expressions are derived for axially loaded beam-columns with constant lateral loads.

FRAMES AND ARCHES

82-2173

The Effect of Joint Properties on the Vibrations of Timoshenko Frames

I. Yaghmai and D.A. Frohrib

Dept. of Mech. Engrg., Shariff Univ. of Tech., Tehran, Iran, Shock Vib. Bull. 52, Part 5, pp 19-27 (May 1982) 7 figs, 15 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Frames, Natural frequencies, Joints (junctions), Timoshenko theory

Mechanical support fixtures comprised of short beams and joints have natural frequencies which may differ appreciably from predictions based on slender beam theory and which neglect joint properties. This paper presents information on the role of Timoshenko effects and joining properties on the first several natural frequencies of frame structures. The interaction between these properties and the number of vertical bays of the structure is also portrayed.

PANELS

82-2174

Free Vibration of Formed Sandwich Panel

K.P. Chong, Y.K. Cheung, and L.G. Tham

Dept. of Civil Engrg., Univ. of Wyoming, Laramie, Wyoming 82071, J. Sound Vib., 81 (4), pp 575-582 (Apr 22, 1982) 5 figs, 4 tables, 21 refs

Key Words: Panels, Sandwich structures, Vibration response

The free vibration of prefabricated architectural sandwich panels is studied. The core of the sandwich panel is approximated by finite prisms and the thin faces are modeled by finite strips. The finite prism-strip method is simple to program and saves considerable computing effort when compared with the finite element method. The dynamic characteristics of flat faced homogeneous sandwich panels are compared with results obtained by other methods, and also with the analytical solutions. Several examples are presented for the free vibration of prefabricated architectural sandwich panels.

PLATES

(Also see No. 2154)

82-2175

Large Deflection Random Response of Symmetric Laminated Composite Plates

K.R. Wentz, D.B. Paul, and C. Mei

Air Force Wright Aeronautical Lab., Wright-Patterson AFB, OH, Shock Vib. Bull. 52, Part 5, pp 99-111 (May 1982) 9 figs, 1 table, 20 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Plates, Rectangular plates, Composite materials, Layered materials, Acoustic excitation, Random excitation

Large amplitude response of symmetric laminated rectangular plates subjected to broadband random acoustic excitation is studied analytically. The boundary conditions considered are all the edges simply supported and all the edges clamped. The inplane edge conditions considered are immovable and movable for each of the above cases. Analytical results are verified through comparison with experimental data. The results obtained can be used in the sonic fatigue design of composite aircraft panels.

82-2176

Analysis of Roller-Induced Residual Stresses in Circular Discs and Their Effect on Disc Vibration

G.S. Schajer

Ph.D. Thesis, Univ. of California, Berkeley, 108 pp (1981)

DA8212096

Key Words: Disks, Rotating structures, Stiffness coefficients, Natural frequencies

Rotating circular discs are the basic elements of many different machine types such as steam turbines, computer memories and circular saws. Transverse vibrational instability of such discs can lead to serious operational problems, and so a large disc thickness is often used to ensure adequate disc stiffness and natural frequencies. However, this approach is not always acceptable, and in this study an alternative procedure is described where the stiffness and natural frequencies of a thin circular disc are modified by means of in-plane roller-induced residual stresses.

82-2177

Vibration of Curved Plate Assemblies Subjected to Membrane Stresses

D.J. Dawe and I.R. Morris

Dept. of Civil Engrg., Univ. of Birmingham, Birmingham B15 2TT, UK, J. Sound Vib., 81 (2), pp 229-237 (Mar 22, 1982) 3 figs, 5 refs, 1 table

Key Words: Plates, Natural frequencies, Curved plates, Finite strip method, Membranes

In a previous paper the finite strip method was applied to the prediction of the natural frequencies of vibration of longitudinally invariant, rigidly connected assemblies of circularly curved and flat strips having diaphragm end supports. This work is extended here to include the presence of an initial membrane stress field. An individual curved strip may be subjected to a biaxial direct stress field comprising a uniform stress acting in the circumferential direction and a non-uniform stress acting in the longitudinal direction. The presence of the membrane stress field is accommodated in the analysis by the inclusion of an initial stress or geometric stiffness matrix. A further extension included here is a facility to delete in-surface inertia terms. Results are presented for the application of the strip method in predicting the frequencies of vibration of a circular cylinder subjected to a complicated membrane stress system.

82-2178

Natural Frequencies of Clamped Orthotropic Skew Plates

T. Sakata and T. Hayashi

Chubu Inst. of Tech., Dept. of Mech. Engrg., Kasugai, Nagoya-sub., 487 Japan, J. Sound Vib., 81 (2), pp 287-298 (Mar 22, 1982) 4 figs, 7 tables, 17 refs

Key Words: Plates, Skew plates, Orthotropism, Natural frequencies

Approximate formulae are proposed for estimating natural frequencies of isotropic and specially orthotropic skew plates with clamped sides. It has been shown that one can estimate a natural frequency of a generally orthotropic skew plate with clamped sides by using an approximate formula for the isotropic plate which one can relate to the orthotropic one by applying a reduction method. The accuracy of the proposed approximate formulae is demonstrated by comparing numerical and experimental results for several typical cases.

82-2179

Subharmonic Oscillations of a Prestressed Circular Plate

K. Yasuda and N. Hayashi
Faculty of Engrg., Nagoya Univ., Furocho, Chikusaku, Nagoya, Japan, Bull. JSME, 25 (202), pp 620-630 (Apr 1982) 11 figs, 10 refs

Key Words: Plates, Circular plates, Steel, Subharmonic oscillations, Harmonic excitation

Axisymmetric subharmonic oscillations of a uniformly prestressed circular plate subjected to harmonic excitation are investigated theoretically and experimentally. In the theoretical investigation, modal equations are derived from the von Karman dynamic equations and solved by the method of averaging. The theoretical analysis reveals that subharmonic oscillations of orders 1/2 and 1/3 can occur, and that they are greatly influenced by the prestresses due to internal resonance. Experiments are conducted on a steel plate. The occurrence of the subharmonic oscillations is ascertained experimentally. The theoretical and experimental results are found to agree qualitatively.

82-2180

The Axisymmetrical Steady-State Response of Internally Damped Annular Double-Plate Systems

T. Irie, G. Yamada, and Y. Muramoto
Dept. of Mech. Engrg., Hokkaido Univ., Kita-13, Nishi-8, Kita-ku, Sapporo, 060 Japan, J. Appl. Mech., Trans. ASME, 49 (2), pp 417-424 (June 1982) 11 figs, 1 table, 12 refs

Key Words: Plates, Internal damping, Periodic response, Flexural vibration

The axisymmetrical steady-state response of an internally damped, annular double-plate system interconnected by several springs uniformly distributed along concentric circles to a sinusoidally varying force is determined by the transfer matrix technique. Once the transfer matrix of an annular plate has been determined analytically, the response of the system is obtained by the product of the transfer matrices of each plate and the point matrices at each connecting circle. By the application of the method, the driving-point impedance, transfer impedance, and force transmissibility are calculated numerically for a free-clamped system and a simply supported system.

82-2181

Nonlinear Oscillations of Laminated, Anisotropic, Rectangular Plates

J.N. Reddy and W.C. Chao
Dept. of Engrg. Sci. and Mech., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Appl. Mech., Trans. ASME, 49 (2), pp 396-402 (June 1982) 6 figs, 36 refs

Key Words: Plates, Rectangular plates, Layered materials, Anisotropic properties, Flexural vibration, Natural frequencies

A finite-element analysis of the equations governing the large-amplitude, free, flexural oscillations of laminated, anisotropic, rectangular plates is presented. The equations account for transverse shear strains as well as large rotations. Numerical results of nonlinear fundamental frequencies are presented for rectangular plates of both angle-ply and cross-ply constructions. The effects of amplitude, boundary conditions, transverse shear, aspect ratio, orientation of layers, and materials anisotropy on natural frequencies are investigated. The present finite element results agree with other approximate solutions available in the literature.

82-2182

On the Solutions to Forced Motions of Rectangular Composite Plates

J.N. Reddy
Dept. of Engrg. Sci. and Mech., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Appl. Mech., Trans. ASME, 49 (2), pp 403-408 (June 1982) 4 figs, 3 tables, 28 refs

Key Words: Plates, Rectangular plates, Composite materials, Forced vibrations

For two different lamination schemes, under appropriate boundary conditions and sinusoidal distribution of the transverse load, the exact form of the spatial variation of the solution is obtained, and the problem is reduced to the

solution of a system of ordinary differential equations in time, which are integrated numerically using Newmark's direct integration method. Numerical results for deflections and stresses are presented showing the effect of plate side-to-thickness ratio, aspect ratio, material orthotropy, and lamination scheme. The results presented herein should be of interest to composite-structure designers, and to experimentalists and numerical analysts in verifying their results.

82-2183

Energy Transmission in Finite Coupled Plates, Part I: Theory

J.L. Guyader, C. Boisson, and C. Lesueur

Vibration-Acoustic Lab. of the Natl. Inst. of Appl. Sciences, 69621 Villeurbanne Cedex, France, J. Sound Vib., 81 (1), pp 81-92 (Mar 8, 1982) 2 figs, 13 refs

Key Words: Plates, Energy transmission, Vibration transfer, Coupled systems, Buildings, Modal analysis

A theoretical method for studying vibrational energy transmission in coupled structures, which differs radically from the previous statistical energy analysis studies, is presented. This method is based on a modal description of the global structure. General expressions are obtained for energies of the coupled substructures, and three different mechanisms of coupling are shown: spectral, spatial and excitation coupling. The important practical case of coupled plates forming an L, T or cross junction, is then treated and analytical expressions of the global eigenmodes are given.

82-2184

Energy Transmission in Finite Coupled Plates, Part II: Application to an L Shaped Structure

C. Boisson, J.L. Guyader, P. Millot, and C. Lesueur

Vibration-Acoustic Lab. of the Natl. Inst. of Appl. Sciences, 69621 Villeurbanne Cedex, France, J. Sound Vib., 81 (1), pp 93-105 (Mar 8, 1982) 16 figs, 2 tables, 8 refs

Key Words: Plates, Energy transmission, Vibration transfer, Damping effects, Geometric effects, Buildings

The method presented in Part I is applied to the case of two thin plates coupled in an L shape. Numerical calculations yield values of the vibrational energies of each plate. The influences of damping, thickness and area of the plates and of the excitation type are presented and discussed. The theoretical results are compared with results from a computerized experiment, in which special attention is given to the number and position of point velocity measurements.

SHELLS

(Also see No. 2142)

82-2185

Theory of Viscoplastic Shells for Analysis of Dynamic Response

R.S. Atkatsh

Ph.D. Thesis, Columbia Univ., 63 pp (1982)
DA8211081

Key Words: Shells, Viscoplastic properties, Dynamic response, Computer programs

A viscoplastic shell model is formulated which utilizes the shell membrane strains and curvatures as the kinematic variables and the shell stress resultants (membrane forces and moments) as the dynamic variables. The viscoplastic shell model combines the concept of Perzyna's viscoplastic constitutive equations with Bieniek's shell stress resultant formulation. The model is incorporated into the Elasto-Plastic Shell Analysis code for the analysis of shells in an acoustic medium subjected to dynamic loadings which produce large elasto-viscoplastic deformations in the shell. Several examples are presented to exhibit the effect of material rate dependence upon structural response.

82-2186

Cooling Tower Shells Founded on Soil

O.M. El-Shafee and P.L. Gould

Dept. of Civil Engrg., Washington Univ., St. Louis, MO, ASCE J. Struc. Div., 108 (4), pp 800-813 (Apr 1982) 12 figs, 5 tables, 15 refs

Key Words: Shells, Shells of revolution, Cooling towers, Finite element technique, Substructuring methods, Seismic response, Wind induced excitation

A dynamic axisymmetric finite element model suitable for shells of revolution founded on ring footings is presented. The model consists of high-precision rotational shell finite elements, representing the axisymmetric shell, supported on an equivalent boundary system, representing the soil medium. The substructure method is used to model the shell and soil components. In addition to the seismic analysis capability of the proposed model, it is also applicable to other dynamic loads such as wind. The dynamic behavior of a hyperboloidal cooling tower shell on discrete supports with a ring footing is studied. Dynamic properties are examined and stress analysis is carried out for a variety of soil conditions.

82-2187

Dynamic Buckling of Inelastic Spherical Shells

G.E. Funk and L.H.N. Lee
Space Systems Group, Rockwell International, Los Angeles, CA 90241, J. Pressure Vessel Tech., Trans. ASME, 104 (2), pp 79-87 (May 1982) 6 figs, 10 refs

Key Words: Shells, Spherical shells, Dynamic buckling

The dynamic buckling behavior of a complete spherical shell made of a bilinear or work-hardening material and under a uniform external impulsive loading is investigated. A quasi-bifurcation theory and a minimum principle are employed to determine, respectively, the onset of the dynamic buckling process and the post-bifurcation nonlinear behavior. Numerical results are obtained for a number of elastic and elastic-plastic cases. The results indicate there is a softening effect in the plastic deviated stress-strain relationship which makes the spherical shell less stable. Furthermore, the higher order terms in stress and strain measures and the coupling of symmetric and asymmetric modes of motion cannot be neglected in the post-bifurcation analysis.

82-2188

Vibration of Cylindrical Shells of Bimodulus Composite Materials

C.W. Bert and M. Kumar
School of Aerospace, Mechanical and Nuclear Engrg., The Univ. of Oklahoma, Norman, OK 73019, J. Sound Vib., 81 (1), pp 107-121 (Mar 8, 1982) 5 figs, 9 tables, 37 refs

Key Words: Shells, Cylindrical shells, Composite materials, Variable material properties, Vibration response, Small amplitudes

A theory is formulated for the small amplitude free vibration of thick, circular cylindrical shells laminated of bimodulus composite materials, which have different elastic properties depending upon whether the fiber-direction strain is tensile or compressive. The theory used is the dynamic, shear deformable (moderately thick shell) analog of the Sanders best first approximation thin shell theory. By means of tracers, the analysis can be reduced to that of various simpler shell theories, namely Love's first approximation, and Donnell's shallow shell theory. As an example of the application of the theory, a closed form solution is presented for a freely supported panel or complete shell. To validate the analysis, numerical results are compared with existing results for various special cases. Also, the effects of the various shell theories, thickness shear flexibility, and bimodulus action are investigated.

82-2189

Characteristics of Wave Propagation and Energy Distributions in Cylindrical Elastic Shells Filled with Fluid

C.R. Fuller and F.J. Fahy
Inst. of Sound and Vib. Res., Univ. of Southampton, Southampton S09 5NH, UK, J. Sound Vib., 81 (4), pp 501-518 (Apr 22, 1982) 9 figs, 1 table, 14 refs

Key Words: Shells, Ducts, Cylindrical shells, Elastic properties, Fluid-filled containers, Wave propagation, Energy dissipation

The dispersion behavior and energy distributions of free waves in thin walled cylindrical elastic shells filled with fluid are investigated. Dispersion curves are presented for a range of parameters and the behavior of individual branches is explained. A non-dimensional equation which determines the distribution of vibrational energy between the shell wall and the contained fluid is derived and its variation with frequency and material parameters is studied.

82-2190

Seismic Design of Flexible Cylindrical Liquid Storage Tanks

T. Balendra, K.K. Ang, P. Paramasivam, and S.L. Lee
Dept. of Civil Engrg., Natl. Univ. of Singapore, Singapore, Earthquake Engrg. Struc. Dynam., 10 (3), pp 477-496 (May-June 1982) 15 figs, 3 tables, 15 refs

Key Words: Shells, Cylindrical shells, Storage tanks, Seismic design

Seismic response of cylindrical storage tanks anchored to rigid base slabs is considered. Finite elements are used for the liquid and tank wall, idealized as a thin shell. For steel tanks of practical dimensions, design charts are presented for natural frequencies, maximum shear and overturning moment on the foundation, and maximum stress resultants in the tank wall. An analytical expression for the superelevation of the free surface is also presented.

82-2191
Free Vibration of a Conical Shell with Variable Thickness
T. Irie, G. Yamada, and Y. Kaneko
Dept. of Mech. Engrg., Hokkaido Univ., Sapporo 060, Japan, J. Sound Vib., 82 (1), pp 83-94 (May 8, 1982) 8 figs, 2 tables, 14 refs

Key Words: Shells, Conical shells, Variable cross section, Natural frequencies, Mode shapes

An analysis is presented for the free vibration of a truncated conical shell with variable thickness by use of the transfer matrix approach. The applicability of the classical thin shell theory is assumed and the governing equations of vibration of a conical shell are written as a coupled set of first order differential equations by using the transfer matrix of the shell. Once the matrix has been determined by quadrature of the equations, the natural frequencies and the mode shapes of vibration are calculated numerically in terms of the elements of the matrix under any combination of boundary conditions at the edges. The method is applied to truncated conical shells with linearly, parabolically or exponentially varying thickness, and the effects of the semi-vertex angle, truncated length and varying thickness on the vibration are studied.

82-2192
Vibration and Acoustic Radiation from Point Excited Spherical Shells
E.H. Wong and S.I. Hayek
Naval Ocean Systems Ctr., San Diego, CA 92152, Shock Vib. Bull. 52, Part 5, pp 135-148 (May 1982) 23 figs, 1 table, 11 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Shells, Spherical shells, Aluminum, Vibration response

The vibrational and acoustic nearfield of thin aluminum spherical shells were investigated analytically and experimentally. Two such shells with thickness-to-radius ratios of 6.4×10^{-3} and 13.4×10^{-3} were excited by an impedance head at the apex, simulating a mechanical point excitation. The driving point admittance frequency spectra of the shells when excited in air were recorded and at each maximum, the mode shape at resonance was plotted. These measurements were repeated when the shell was suspended in a large water tank. The driving point admittance of the submerged shells was recorded. The mode shapes at resonance were plotted by use of a small hydrophone that measured the nearfield pressure of the vibrating shells. A parallel analytic prediction of the amplitude of the vibration, the nearfield and farfield pressures were made.

82-2193
Dynamic Characteristics of a Non-Uniform Torpedo-Like Hull Structure
A. Harari
Naval Underwater Systems Ctr., Newport, RI 02840, Shock Vib. Bull. 52, Part 5, pp 113-133 (May 1982) 5 refs, 10 figs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Torpedoes, Shells, Cylindrical shells, Vibration control

The vibratory response of a torpedo-like structure is investigated. The torpedo hull is characterized by a long cylindrical shell where the length-to-radius ratio is large. The cylindrical shell is built from several sections that may differ in thickness and material properties. The response of the structure to various loading conditions is found and the results presented. Reduction of the vibration level of the torpedo hull at the frequency band of interest can be accomplished only after the response of the structure is well understood.

RINGS

82-2194
The Steady State Out-of-Plane Response of an Internally Damped Ring Supported by Springs in Some Bays
T. Irie, G. Yamada, and H. Koizumi
Dept. of Mech. Engrg., Hokkaido Univ., Sapporo 060, Japan, J. Sound Vib., 81 (2), pp 187-197 (Mar 22, 1982) 6 figs, 18 refs

Key Words: Rings, Elastic foundations, Springs, Internal damping, Transfer matrix method

The steady state out-of-plane response of an internally damped ring supported by springs in some bays to a sinusoidally varying point force or moment is determined by use of the transfer matrix technique. For this purpose, the equations of out-of-plane vibration of a uniform circular ring based upon the Timoshenko beam theory are written as a coupled set of first order differential equations by using the transfer matrix of the ring. The matrix is obtained analytically and the steady state response of the ring is determined by the product of the matrices in free bays and those in supported bays.

PIPES AND TUBES

82-2195

Acoustic Propagation in a Rigid Torus

M. El-Raheb and P. Wagner
Appl. Mech., Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91109, J. Acoust. Soc. Amer., 71 (6), pp 1335-1346 (June 1982) 10 figs, 3 tables, 24 refs

Key Words: Pipes (tubes), Curved pipes, Ducts

The acoustic propagation in a rigid torus is analyzed using a Green's function method. Three types of surface elements are developed; a flat quadrilateral element used in modeling polygonal cavities, a curved conical element appropriate for surfaces with one curvature, and a toroidal element developed for such doubly curved surfaces as the torus.

82-2196

Sound Propagation in a Pipe Containing a Liquid of Comparable Acoustic Impedance

M.P. Horne and R.J. Hansen
Marine Tech. Div., Naval Res. Lab., Washington, DC 20375, J. Acoust. Soc. Amer., 71 (6), pp 1400-1405 (June 1982) 9 figs, 2 tables, 8 refs

Key Words: Pipes (tubes), Fluid-filled containers, Sound propagation

A detailed experimental study of sound propagation in liquids contained by pipes constructed of polymeric materials is discussed. Experiments were conducted with vertically aligned cylinders containing water ensonified at one end by a piston-driven sound source. Significant sound attenuation (as much as 60 dB) was observed in pipes made of flexible polymeric materials, the effect increasing with frequency and loss tangent. Sound propagation in more rigid polymeric pipes exhibited similar characteristics to that in metallic pipe in that negligible attenuation was observed.

82-2197

Free-Wave Propagation in Fluid-Loaded Thick-Walled Circular Pipes

S.A. Lester
Admiralty Marine Technology Establishment, Teddington, UK, Rept. No. AMTE(N)-TM81093, DRIC-BR-81307, 17 pp (Nov 1981)
AD-A111 309

Key Words: Pipes (tubes), Submerged structures, Fluid-filled containers, Wave propagation

An infinite thick-walled pipe contains, and is surrounded by, an inviscid fluid. The displacements of the pipe's wall satisfy the exact linear equations of elasticity, and the interior and exterior fluids satisfy the scalar Helmholtz wave equation. The differential equations are solved by means of Fourier transforms to give the dispersion relation connecting frequency with axial and circumferential wavenumbers. The dispersion relation is solved numerically to give examples of real axial wave number versus frequency plots for selected circumferential harmonics.

82-2198

Seismic Hazard Analysis of Lifelines

J. Mohammadi and A.H.-S. Ang
Illinois Inst. of Tech., Chicago, IL, ASCE J. Struc. Div., 108 (6), pp 1232-1249 (June 1982) 11 figs, 3 tables, 15 refs

Key Words: Lifeline systems, Seismic response, Earthquake damage

Methods for assessing the seismic safety of a lifeline system are developed; with part of the study being devoted to the development of a relation between the earthquake intensity and the distance for near-source regions. The attenuation of maximum ground motion intensity with distance is examined. Specific attenuation relations are developed and compared with the existing empirical attenuation equations. On this basis, the importance of the source parameters are examined.

82-2199

Whirling Instabilities in Heat Exchanger Tube Arrays

G.S. Whiston and G.D. Thomas
Central Electricity Res. Labs., Kelvin Ave., Leatherhead KT22 7SE, UK, J. Sound Vib., 81 (1), pp 1-31 (Mar 8, 1982) 7 figs, 1 table, 12 refs

Key Words: Tube arrays, Heat exchangers, Whirling

The simple position-dependent whirling mechanism proposed by Blevins for single across-stream tube rows is extended to

model the effects of mechanical coupling between tubes and whirling in two dimensional tube banks. The model is in reasonable agreement with experiment for staggered arrays but not for in-line arrays. A wake galloping model is suggested fc in-line arrays which is capable of producing agreement with experiment. The use of the Pettigrew design criteria for tube banks is also critically assessed. It is suggested that the usu of a fixed "whirling" constant K for all structural mode shapes of a tube array may be too restrictive for low frequency, long wavelength modes, whereas a "whirling" constant dependent on tube array mode shape is more useful for design purposes. A discussion has been included of the relevance to real heat exchangers of flow tests on uncoupled tube arrays and the effects of detuning tubes in such arrays.

82-2200
Random Coupled Vibration of Bundles of Elastic Rods
D. Dincă
Natl. Inst. for Scientific and Technical Creation, Bucharest, Romania, Mech. Res. Comm., 9 (2), pp 95-100 (Mar/Apr 1982) 3 figs, 1 table, 4 refs

Key Words: Tube arrays, Beams, Viscoelastic properties, Rods, Fluid-induced excitation, Random excitation, Rayleigh method, Timoshenko theory

Solving the practical problems of nuclear fuel bundles, heat exchanger tubes, or parallel pipelines, requires the analysis of viscoelastic structures immersed in a fluid and acted upon by random loads. A detailed study of a bundle of parallel rods immersed in an ideal fluid was made using beam theory and considering each rod as a Bernoulli-Euler one. In this paper the Bernoulli-Euler model was replaced with two other more accurate models: the Rayleigh model, which takes into account the rotatory inertia effect and the Timoshenko model, which takes into account both the rotatory inertia effect and the shear forces effect.

DUCTS
(Also see No. 2189)

82-2201
The Influence of Flow on the Acoustic Characteristics of a Duct Bend for Higher Order Modes - A Numerical Study
A. Cabelli
Div. of Energy Tech., Commonwealth Scientific and Industrial Res. Organization, Melbourne, Australia, J. Sound Vib., 82 (1), pp 131-149 (May 8, 1982) 9 figs, 3 tables, 26 refs

Key Words: Ducts, Curved ducts, Sound transmission, Acoustic reflection, Numerical analysis

A numerical technique was used to investigate the effects of flow on the acoustic transmission and reflection characteristics of a duct bend. The range of wave numbers examined extended to the cut-on value of the second cross-mode. Characteristics were studied in terms of the velocity potential, the acoustic pressure and the energy flux. The effects of locating a turning vane centrally in the bend were also examined in terms of the energy flux.

82-2202
Acoustic Propagation in Partially Choked Converging-Diverging Ducts
J.J. Kelly, A.H. Nayfeh, and L.T. Watson
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 81 (4), pp 519-534 (Apr 22, 1982) 12 figs, 30 refs

Key Words: Ducts, Acoustic linings, Elastic waves, Sound propagation

A computer model based on the wave-envelope technique is used to study acoustic propagation in converging-diverging hard walled and lined circular ducts carrying near sonic mean flows. The influences of the liner admittance, boundary layer thickness, spinning mode number, and mean Mach number are considered. The numerical results indicate that the diverging portion of the duct can have a strong reflective effect for partially choked flows.

82-2203
General Mapping Procedure for Variable Area Duct Acoustics
J.W. White
Univ. of Tennessee, Knoxville, TN, AIAA J., 20 (7), pp 880-884 (July 1982) 6 figs, 34 refs

Key Words: Ducts, Variable cross section, Sound propagation, Mappings (mathematics)

A general mapping procedure is described and applied to the study of noise propagation in variable area ducts. The mapping provides a boundary fitted coordinate system which is ideal for the finite-difference solution of acoustic fields with irregular boundaries, without the burden of large matrices required by finite element methods. The procedure is first described in general and then applied to a particular two-dimensional geometry under current experimental investigation. This method should be ideally suited to the study of high-frequency noise propagation in variable area ducts and in cases where the far field is included in the calculation procedure.

BUILDING COMPONENTS

(Also see Nos. 2183, 2184)

82-2204

Measurement of Mobility and Damping of Floors

M.F. White and K.H. Liasjø

Akustisk Laboratorium/ELAB, N-7034 Trondheim-NTH, Norway, J. Sound Vib., 81 (4), pp 535-547 (Apr 22, 1982) 14 figs, 3 tables, 7 refs

Key Words: Floors, Buildings, Damping coefficients, Mobility functions, Machine foundations

Point mobility and damping (loss factor) were measured for different types of wooden and concrete floors in occupied buildings. A vertically applied excitation force was used. Various types of woodworking machines and workshop equipment were present during the tests in order to give a practical measure of floor damping. For comparison, the characteristics of a free concrete slab with point supports at each corner, a newly constructed unfurnished office building, and an experimental floating floor were also measured.

82-2205

Dynamic Characteristics of Frame-Wall Systems

A.K. Basu, A.K. Nagpal, and A.K. Nagar

Indian Inst. of Tech., New Delhi, India, ASCE J. Struc. Div., 108 (6), pp 1201-1218 (June 1982) 10 figs, 5 tables, 5 refs

Key Words: Multistory buildings, Framed structures, Walls, Natural frequencies, Mode shapes, Transverse shear deformation effects

The first three natural frequencies and the corresponding mode shapes for fixed-base frame-wall systems are presented. The system is modeled as a continuum of uniform properties incorporating the shear deformation in the wall. The resulting fourth-order homogeneous differential equation in terms of lateral displacement is solved exactly using an appropriate numerical technique. The results are presented for various combinations of the two nondimensional parameters which together incorporate all the geometric and material properties of the frame-wall system.

ELECTRIC COMPONENTS

TRANSFORMERS

82-2206

Transformer Noise

W.M. Schuller

Peutz & Associates, P.O. Box 407, Nijmegen, The Hague, The Netherlands, Noise Control Engrg., 18 (3), pp 111-116 (May-June 1982) 13 figs, 9 refs

Key Words: Transformers, Noise generation, Noise reduction

Transformer noise can be characterized by pure tones at the even harmonics of the main frequency and noise generated by fans of the cooling system. The main cause of transformer noise is the magnetostriction of the core iron, which leads to core and tank vibration and so to noise. Reduction of transformer noise at the source includes selection of core material and of core construction. Furthermore, fans of the cooling system, radiation of the tank, and construction of the foundation may play an important role in the noise production process. Barriers with sufficient screening and isolation, sometimes with tuned absorption, may reduce noise by 10 dB(A). Enclosures exist both for transformers with and without a cooling system. In the latter case, reduction of up to approximately 35 dB(A) can be realized. Examples, including acoustical results and cost, are given.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

(Also see Nos. 2063, 2070, 2096)

82-2207

Active Attenuation of Noise – The State of the Art

G.E. Warnaka

Lord Corp., 2000 W. Grandview Blvd., Erie, PA 16514, Noise Control Engrg., 18 (3), pp 100-110 (May-June 1982) 17 figs, 74 refs

Key Words: Noise reduction, Active noise control

The principle of superposition implies that it is possible to cancel noise by using anti-noise. This relatively old concept can now be made useful in practical noise control problems by using modern electronic circuits to analyze the noise and develop a 180° out-of-phase signal of the same intensity. The work done over nearly 50 years is reviewed and some of the problems still remaining in this field are discussed along with the considerable progress made.

82-2208

Noise Control in Ring Spinning Rooms

G. Mandl

Rieter Machine Works Ltd., CH-8406 Winterthur, Switzerland, Noise Control Engrg., 18 (3), pp 93-99 (May-June 1982) 11 figs, 3 tables, 6 refs

Key Words: Spindles, Noise reduction, Industrial facilities, Noise generation

In the United States textile workers run the risk of hearing impairment from approximately 17 million loud textile spindles. This situation is reviewed and the sound-field is described. Analysis of the situation leads to a modified type of machinery which satisfies the demands for low sound emission and mill suitability.

82-2209

Controlling Employee Exposure to Varying Noise Levels

M.S. Hundal

Dept. of Mech. Engrg., Univ. of Vermont, Burlington, VT, Plant Engrg., 36 (12), pp 121-124 (June 10, 1982) 6 figs

Key Words: Industrial facilities, Noise generation, Noise reduction

Permissible industrial noise levels, noise measurement and noise reduction techniques are discussed.

82-2210

Theoretical Foundations of Some Problems of Environmental Acoustics

R. Makarewicz

Inst. of Acoustics, Adam Mickiewicz Univ., 60-769 Poznań, Poland, J. Sound Vib., 81 (2), pp 271-286 (Mar 22, 1982) 14 figs, 27 refs

Key Words: Noise generation, Traffic noise, Noise reduction

A description of the sound field of moving sources, in terms of the average intensity of the sound over time, is given. Results have been obtained under the assumption that the sources are moving at a constant speed, near to a flat surface with uniform cover. The description presented should be useful for traffic noise control problems and some questions related to town and country planning.

82-2211

The Prediction of Sound Fields in Non-Diffuse Spaces by a "Random Walk" Approach

E. Kruzins and F. Fricke

Dept. of Architectural Sci., Univ. of Sydney, Sydney, New South Wales 2006, Australia, J. Sound Vib., 81 (4), pp 549-564 (Apr 22, 1982) 10 figs, 3 tables, 6 refs

Key Words: Enclosures, Sound pressure levels, Noise prediction

A Markov process, representing random walks of acoustical phonons in an enclosure, is used to predict the steady state high frequency sound pressure levels in complex internal spaces, excited by an omni-directional point source. In the theory, developed from work by Gerlach, one considers the three dimensional random walks of phonons inside an enclosure of any internally complex geometry. The sound pattern is derived by considering the probability that a phonon, leaving some source, will radiate to a particular wall, undergo a certain path of successive reflections, and be radiated to a detection point. The spatial density of phonons, at a given location, arising from a large ensemble of phonons traversing different random paths, gives rise to an intensity. Knowledge of the sound intensity at a suitable number of detection points, in a regularly spaced lattice, enables the sound field inside an enclosure to be estimated.

82-2212

Sound Radiation from a Housing Containing an Acoustic Source

K. Umezawa, M. Kobayashi, and H. Houjoh

Res. Lab. of Precision Machinery and Electronics, Tokyo Inst. of Tech., Nagatsuta, Yokohama, Japan, Bull. JSME, 25 (202), pp 638-645 (Apr 1982) 16 figs, 3 tables, 16 refs

Key Words: Enclosures, Sound transmission, Gear boxes, Steel, Acoustic holography, Noise reduction

To study acoustic transmission path from the inside to the outside of rectangular enclosures, a simple gear box model made of 1.1 mm, 2.3 mm and 9.0 mm steel plates, has been examined by means of acoustical holography.

82-2213

An Analysis of Deep Ocean Sound Attenuation at Very Low Frequencies

K.C. Focke, S.K. Mitchell, and C.W. Horton

Appl. Res. Labs., Univ. of Texas at Austin, Rept. No. ARL-TM-82-1, 33 pp (Jan 6, 1982)

AD-A111 295

Key Words: Underwater sound, Sound attenuation

The attenuation coefficient of low frequency, deep ocean acoustic waves is computed for various assumptions regarding the depth profile and the frequency dependence of the scatterers. The calculations are made for a realistic velocity profile by means of a perturbation technique proposed by Guthrie. It is shown that excellent agreement with experimental data is obtained when the attenuation function is independent of frequency and decreases exponentially with depth of 200-500 m.

SHOCK EXCITATION

(Also see Nos. 2114, 2276, 2278, 2281)

82-2214

Gunfire Vibration Simulation on a Digital Vibration Control System

J. Cies

Hewlett-Packard Co., Paramus, NJ, Shock Vib. Bull. 52, Part 3, pp 11-18 (May 1982) 10 figs, 1 table, 2 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Aircraft vibration, Gunfire effects, Simulation, Computerized simulation, Digital techniques

This paper describes a method of synthesizing a shaped pulse train required to simulate gunfire vibration. The pulse train yields the desired line spectrum resulting from machine gun firing vibration excitation on a typical military aircraft. The shaped line spectrum comes directly from the specification. The shape is determined by the location on the aircraft and the line spacing depends upon the firing rate of the gun. In addition to giving the line spectrum, some of the current specifications for this vibration environment detail how to set-up the test using analog equipment. A comparison with the digital system approach method is included and the extraneous data of the specification is discussed as it applies to the digital controller. It is also intended to compare the digital system method to actual recorded acceleration data taken from a test firing of one of these Gatling guns.

82-2215

Force Optimized Recoil Control System

P.E. Townsend, R.J. Radkiewicz, and R.F. Gartner

US Army Armament Res. and Dev. Command, Dover, NJ, Shock Vib. Bull. 52, Part 4, pp 55-71 (May 1982) 10 figs, 1 table (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Gunfire effects, Shock excitation, Vibration control

This paper will discuss a fire-out-of-battery concept for reducing gun peak recoil loads and test results obtained from two significantly different automatic, rapid fire guns. This Force Optimized Recoil Controller (FORC) system reduced the transmitted recoil loads from the firing guns by over 70% when compared to recoil loads measured when using conventional recoil adapters.

82-2216

Indirect Fourier Transform (IFT) and Shock Response – a Detailed Presentation of Basic Theory

C.T. Morrow

Encinitas, CA, Shock Vib. Bull. 52, Part 4, pp 37-45 (May 1982) 10 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Shock response spectra, Fourier transformation, Indirect Fourier transform

An algorithm is capable of yielding undamped residual shock spectra and indirect Fourier transforms, with minimal calculator or computer data-memory requirements, and with about the same computation time as with the fast Fourier transform (FFT). For the same number of frequencies in the spectrum, computation is slower than with the FFT algorithm, but the latter fundamentally requires many more frequencies than are otherwise necessary for spectral analysis of shock. With minor alteration, the IFT algorithm can yield quite simply the instantaneous responses of undamped or damped linear and some nonlinear mechanical systems. The algorithm is presented here essentially as originally developed for the HP-97 card-programmable calculator.

82-2217

Turbulence Amplification in Shock-Wave Boundary-Layer Interaction

J.C. Anyiwo and D.M. Bushnell
NASA Langley Res. Ctr., Hampton, VA, AIAA J., 20 (7), pp 893-899 (July 1982) 5 figs, 27 refs

Key Words: Shock wave propagation, Turbulence

Attention is directed to the acoustics research of the 1950s and 1960s for guidance in understanding and quantizing the turbulence amplification that can occur in regions of shock-wave boundary-layer interaction. Three primary turbulence amplifier-generator mechanisms are identified and shown by linear analysis, to be responsible for turbulence amplification across a shock wave in excess of 100% of the incident turbulence intensity.

82-2218

Study on Impact of Equivalent Two Bodies (Coefficients of Restitution of Spheres of Brass, Lead, Glass, Porcelain and Agate, and the Material Properties)

Y. Tatara and N. Moriwaki
Faculty of Engrg., Shizuoka Univ., Hamamatsu-city, Shizuoka-prefecture, 3-5-1 Johoku-machi, Japan, Bull. JSME, 25 (202), pp 631-637 (Apr 1982) 9 figs, 2 tables, 10 refs

Key Words: Impact response, Spheres, Restitution coefficient

Although current equations for coefficient of restitution in the central impact of solid spheres were presented only empirically as a function of the impact velocity v_i, theoretical equations for the coefficients of restitution as a function of v_i for the impact of spheres of equal diameter and equal material are presented in this study under the assumption that the separation of the impacting spheres is determined at the zero relative displacement. Through comparison of results measured here using two ball pendulums for spheres of brass, lead, glass, porcelain and agate, the viscous nature of the materials is estimated.

82-2219

Use of a Dropped Weight to Simulate a Nuclear Surface Burst

C.R. Welch and S.A. Kiger
Corps of Engineers, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Shock Vib. Bull. 52, Part 3, pp 65-76 (May 1982) 9 figs, 16 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Nuclear explosions, Ground shock, Simulation, Underground structures

This paper investigates analytically and experimentally the use of a dropped weight for the simulation of the airblast generated ground shock from a nuclear surface burst. A one-dimensional elastic analytical model of the weight impacting the soil is presented. Measured stress and particle velocity wave forms from a series of dropped-weight tests are presented along with the calculated stress wave forms. Limitations and difficulties associated with the dropped-weight simulation technique are discussed as well as problems with displacement boundary conditions, impact planarity requirements, and the smallness of the test bed. Applications of the drop-weight technique to the testing of model underground structures are discussed.

82-2220

Cable Protection for Ground Shock Instrumentation in Severe Environments - Results of an Evaluation Test

C.R. Welch
Corps of Engineers, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Shock Vib. Bull. 52, Part 3, pp 31-42 (May 1982) 16 figs, 1 table, 3 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Explosion effects, Measuring instruments, Ground shock

The results of an explosive test on two candidate cable protection systems for ground shock instrumentation are pre-

sented. The protection systems consisted of 1/4-in. stainless steel (304 alloy) tubing and 3/8-in. oil-filled hydraulic hose. Typical data return from several later tests which employed these two systems is then reviewed.

82-2221
On Dynamic Fracture of Rock under Bit Impact Loads

I.E. Eronini

Howard Univ., Washington, DC 20059, J. Engrg. Resources Tech., Trans. ASME, 104 (2), pp 105-107 (June 1982) 5 figs, 1 table, 10 refs

Key Words: Rocks, Impact response, Fracture

A characterization of the dynamic interaction between an impacting tool and rock is presented. The analysis is based on the concept of rock fracture energy and on simple representations of the amount of fracturing and energy storage in the rock during fracture propagation. Simulation results are shown for bit-tooth drop tests on Indiana limestone under different values of the differential pressure across the rock face and for various heights of drop. The predicted dynamic force-penetration curves, force-time, displacement-time and velocity-time histories agree well with reported laboratory data and demonstrate that the essential elements of tooth drop loading are adequately represented by the model.

82-2222
Probability of Survival in Blast Environment

A. Longinow, K.-H. Chu, and N.T. Thomopoulos

Dept. of Civil Engrg., Valparaiso Univ., Valparaiso, IN 46383, ASCE J. Engrg. Mech. Div., 108 (2), pp 309-330 (Apr 1982) 14 figs, 5 tables, 22 refs

Key Words: Protective shelters, Blast response

The probability of survival of people located in personnel shelters when subjected to the blast effects produced by the detonation of a 1-MT weapon near the ground surface is studied. Personnel shelters analyzed are buried or with the roof slab at grade. The analysis considers the variability of selected geometric parameters of the roof slab, material properties and airblast parameters.

82-2223
Structural Response of HEPA Filters to Shock Waves

P.R. Smith and W.S. Gregory

New Mexico State Univ., Las Cruces, NM, Shock Vib. Bull. 52, Part 3, pp 43-51 (May 1982) 7 figs, 3 tables, 4 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Shock tube testing, Ventilation, Nuclear power plants

Shock waves were produced in a shock tube one meter in diameter and 49 meters in length. The driver of the shock tube was of variable length so that both peak pressure and impulse behind the wave could be controlled. Structural behavior of the HEPA filters as shock waves impacted upon them was recorded by a high speed motion picture camera. Various pressure and temperature transducers recorded the characteristics of the shock wave on a high speed recorder. Impulse per unit area needed to break a given brand of filter was found to be constant for long driver lengths. However, for short driver lengths the high velocity air flow behind the shock wave was apparently responsible for filter failure, rather than shock impulse.

82-2224
A Boundary-Element Method for Slamming Analysis

T.L. Geers

Lockheed Palo Alto Res. Lab., Palo Alto, CA, J. Ship Res., 26 (2), pp 117-124 (June 1982) 6 figs, 22 refs

Key Words: Interaction: structure-fluid, Slamming, Impact response

A boundary-element method for treatment of the fluid-structure interaction in slamming analysis is described. The method emphasizes simplicity and efficiency, so that the analyst may devote most of his computational resources to the analysis of the structure. Numerical results for a number of rigid-impactor problems are compared with analytical solutions and experimental data, and procedures for the finite-element analysis of flexible impactors are discussed.

82-2225
Soil Structure Interaction and Soil Models

J.M. Ferritto

Naval Civil Engrg. Lab., Port Hueneme, CA, Shock Vib. Bull. 52, Part 5, pp 29-38 (May 1982) 15 figs, 10 refs (Proc. 52nd Symp. on Shock and Vib., New

Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Interaction: soil-structure, Seismic response

Soil-structure interaction effects can significantly alter the computed seismic behavior of a structure. The accurate characterization of the nonlinear soil behavior is important in considering seismic amplification and attenuation. A detailed discussion of soil models, fitting of parameters and comparison of results is presented. A comparison is given of linear and nonlinear example data.

VIBRATION EXCITATION

(Also see No. 2118)

82-2226

Lagrangian Boundary Condition and Non-Linear Propagation as Causes of Gaussian Noise Spectrum Deformation

R. Dyba and B. Żółtogórski

Inst. of Telecommunication and Acoustics, Wroclaw Technical Univ., 50-370 Wroclaw, Poland, J. Sound Vib., 81 (2), pp 239-253 (Mar 22, 1982) 1 fig, 12 refs

Key Words: Spectrum analysis, Random excitation

A novel analytical method of spectral analysis for acoustic Gaussian noise signals propagated in lossless fluids is presented. The starting point for theoretical considerations is the input signal transformation given by Earnshaw's parametric solution. By using a method of parameter elimination, based upon the filtering property of the delta function and its spectral representation, and utilizing a new theorem concerning continuous stochastic processes, an integral formula which allows one to map the power spectrum of the input signal (i.e., the boundary condition of Lagrange or the boundary condition of Euler) into the power spectrum of the particle velocity for an arbitrary point of the acoustic field (before the shock formation), is derived. The final formulae are well-adapted to numerical calculations of output spectra by electronic means.

82-2227

On the Optimal Location of Vibration Supports

[illegible]. Wang and W.D. Pilkey

Univ. of Virginia, Charlottesville, VA 22901, Shock Vib. Bull. 52, Part 5, pp 55-58 (May 1982) 3 figs, 2 tables, 6 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Natural frequencies, Support location optimization, Antiresonant frequencies

The problem of optimal positioning of vibration supports to raise the fundamental natural frequency of a system is studied. It is proposed that possible locations of the supports can be compared by studying the corresponding antiresonant frequencies. It is contended that a near optimal location is achieved by locating the supports such that the corresponding lowest antiresonant frequency is a maximum and a criterion is proposed. Numerical examples are used to illustrate this criterion.

82-2228

Calculation of Unsteady Transonic Pressure Distributions by the Indicial Method

G.D. Kerlick and D. Nixon

Nielsen Engrg. and Res., Inc., Mountain View, CA 94043, J. Appl. Mech., Trans. ASME, 49 (2), pp 273-278 (June 1982) 6 figs, 10 refs

Key Words: Flutter, Aerodynamic loads, Random excitation, Indicial method, Strained coordinate technique, Perturbation theory

A method for the rapid estimation of complete unsteady transonic pressure distributions is developed. The two key elements of this method are the indicial method and the strained coordinate technique. The indicial method permits the determination of the response of a system to an arbitrary schedule of perturbations once the response of the system to a step change in one of the perturbing variables (the indicial response) is known. The strained coordinate permits the movement of discontinuities in the solution (e.g., shock waves) to occur as the solution develops in time. Together, these two techniques provide detailed information on the time development of pressure distributions over an airfoil that is of use in aeroelastic applications such as control surface flutter and active control design. Examples of both oscillatory and transient perturbations are given.

82-2229

Limit Cycles in Self-Excited Multi-Degree-of-Freedom Systems

J. Rudowski

Inst. of Fundamental Technological Res., Polish Academy of Sciences, Warsaw, Poland, J. Sound Vib., 81 (1), pp 33-49 (Mar 8, 1982) 12 figs, 26 refs

Key Words: Multidegree of freedom systems, Free vibration

A possibility of generating stable multi-frequency almost-periodic limit cycles in n-degree-of-freedom self-excited systems is investigated. Analytical approximate methods are used. Systems with nonlinear forces described by analytical functions are considered. Several examples of two-degree-of-freedom systems with van der Pol terms are analyzed in detail. The effect of nonlinear restoring forces is also considered. The possibility of occurrence of multi-frequency limit cycles is proved by means of analytical methods and confirmed by analogue computer results.

82-2230

The Analysis of Random Vibrations Caused by Multi-Correlated Excitations (Zur Behandlung von Zufallsschwingungen mechanischer Bauteile infolge mehrfachkorrelierter stochastischer Erregungen)

E. Gossmann and H. Waller

Inst. f. Mechanik, Ruhr-Universitat Bochum, D-4630 Bochum, Postfach 2148, Fed. Rep. Germany, Ing. Arch., 52 (1/2), pp 131-141 (1982) 4 figs, 16 refs

(In German)

Key Words: Random vibration, Covariance function, Towers, Wind-induced excitation

In comparison with the well-known method for calculating variances of random vibrations using spectral densities the method of the covariance analysis is illustrated. The efficiency of this method is demonstrated for multi-correlated random excitations which can be found in nature. An example with wind-influenced vibrations of a television tower is discussed for both methods.

82-2231

Oscillatory Damped Distributed Parameter Systems

D.J. Inman

Dept. of Mech. and Aerospace Engrg., State Univ. of New York at Buffalo, Buffalo, NY 14260, Mech. Res. Comm., 9 (2), pp 101-107 (Mar/Apr 1982) 4 refs

Key Words: Continuous parameter method, Damped structures, Viscous damping

Some results on the free vibrations of viscously damped lumped parameter systems were recently presented. This work presented sufficient conditions for each of the modes to oscillate. Results presented in this paper extend this concept to distributed parameter systems and present a sufficient condition for the time response to be oscillatory. Results are applicable to a limited class of vibrating systems (real, self-adjoint positive definite linear systems). Examples are included.

82-2232

The Effect of Phase Shift of Exciting Forces on Flexural Vibration (Einfluss der Phasenverschiebung der Erregerkräfte bei Biegeschwingungen)

H. Sollmann

Technische Universität Dresden, Sektion Grundlagen des Maschinenwesens, Maschinenbautechnik, 31 (5), pp 222-226 (May 1982) 9 figs, 1 table, 5 refs

(In German)

Key Words: Phase effects, Flexural vibration, Resonant response, Amplitude data

The relationships between phase shifted excitation forces and their effect on the motion of masses in the complex plane of a flexurally vibrating system are investigated. The terms, equivalent exciting force and phase angle, used for the analysis of torsional vibration of reciprocating engines, are introduced for the calculation of resonant vibration amplitudes.

82-2233

Study of Mechanical Systems by Means of Random Excitations (Untersuchung mechanischer Systeme mit Hilfe von Zufallserregungen)

A. Lingener

Technische Hochschule Otto von Guericke Magdeburg, Sektion Maschinenbau, Maschinenbautechnik, 31 (5), pp 213-217 (May 1982) 9 figs, 2 tables, 7 refs

(In German)

Key Words: Random excitation

The experimental study of random vibration of mechanical systems is based upon a digital processing of measured values. The behavior of machines and plants is analyzed, transfer and coherence functions are determined and system characteristics are analyzed. Some practical applications are shown.

82-2234

An Ad-Hoc-Model for Chatter Tests at Coupling of Torsional and Transverse Oscillations at Milling Ma-

chines (Ein Ad-hoc-Modell für Ratteruntersuchungen mit Kopplung von Dreh- und Querschwingungen an Fräsmaschinen)
W. Gumpert and N.Q. Ty
Technische Hochschule Karl-Marx-Stadt, Sektion Maschinen-Bauelemente, Maschinenbautechnik, 31 (5), pp 209-212 (May 1982) 6 figs, 6 refs
(In German)

Key Words: Chatter, Machinery, Torsional vibration, Flexural vibration

The existing chatter tests use the linear models of translational motions only for the determination of stability. A method for the calculation of vibrations with nonlinearities is presented. A model for the interaction of flexural vibration between tool and workpiece with torsional vibrations of the main drive is developed.

MECHANICAL PROPERTIES

DAMPING

(Also see Nos. 2078, 2161, 2231)

82-2235
Extraneous Effects in Damping Measurement
R.J. Hooker and S. Prasertsan
Dept. of Mech. Engrg., Univ. of Queensland, St. Lucia, Queensland 4067, Australia, Shock Vib. Bull. 52, Part 4, pp 141-146 (May 1982) 5 figs, 1 table, 4 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Material damping, Measuring instruments

It is shown that for some material damping measurements the assumption that extraneous effects may be ignored on the basis of tests with a low damping specimen is not necessarily valid. Analytical and experimental investigations are reported for a common torsional damping apparatus arrangement in which load is applied to the specimen through end shanks. The experimental results indicate much greater errors associated with end effects than are expected from analytical considerations.

82-2236
An Experimental Study of the Non-Linear Behaviour of a Stranded Cable and Dry Friction Damper
C.S. Chang and Q. Tian
Inst. of Mech., Chinese Academy of Sciences, Beijing, Peking, China, Shock Vib. Bull. 52, Part 4, pp 155-160 (May 1982) 14 figs, 4 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Dampers, Coulomb friction

The nonlinear characteristics of a stranded cable and dry friction damper are shown by its hysteresis loop and dynamic response curves. The fundamental resonant frequency is found to be amplitude-dependent. The damper with a standard stranded cable has a high amplification factor at large amplitudes of vibration. This undesirable characteristic is overcome by adding a spring coil to the central portion of the cable. The modified cable damper is shown to suppress the fundamental resonant vibration of a cantilever structure.

82-2237
Damped Structure Design Using Finite Element Analysis
M.F. Kluesener and M.L. Drake
Univ. of Dayton Res. Inst., Dayton, OH 45469, Shock Vib. Bull. 52, Part 5, pp 1-12 (May 1982) 17 figs, 3 tables, 8 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Viscoelastic damping, Fatigue life, Aircraft

As the performance requirements and the life cycle costs for jet engines and aircraft increase, the need for functional high cycle fatigue (HCF) control is evident. The purpose of this paper is to present the methodology of using finite element analysis to evaluate viscoelastic damping treatments for HCF control. Steps for analyzing passive damping treatments are presented. Design criteria used to evaluate the damping applications, as well as two methods of calculating the structural loss factor are discussed. The results from analyses of a stiffened panel and turbine blade are also presented.

82-2238
A Procedure for Designing Overdamped Lumped Parameter Systems
D.J. Inman and A.N. Andry, Jr.

Dept. of Mech. and Aerospace Engrg., State Univ. of New York at Buffalo, Buffalo, NY 14260, Shock Vib. Bull. 52, Part 5, pp 49-53 (May 1982) 2 figs, 8 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Overdamping, Lumped parameter method, Multidegree of freedom systems

The concept of overdamping common to a single degree of freedom damped linear system is extended to multidegree of freedom damped linear systems. Inequalities involving the mass, damping and stiffness parameters are derived to form a system with a free response which is overdamped in each mode. A general method for designing systems to be overdamped in each mode is indicated. The method is applied to a four degree of freedom model of a Darrieus wind turbine and a design solution for overdamping is presented.

82-2239

Damping of Shallow-Buried Structures due to Soil-Structure Interaction

F.S. Wong and P. Weidlinger

Weidlinger Associates, Menlo Park, CA and New York, NY, Shock Vib. Bull. 52, Part 5, pp 149-154 (May 1982) 5 figs, 5 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Damping, Underground structures, Interaction: soil-structure

Damping of the motion of buried structures is derived based on the mechanics of dynamic soil-structure interaction. The interplay between the structural motion and the soil loading on the structure results directly in the damping of the structural motion. The derivation is illustrated by an example of a horizontal slab embedded in an elastic soil medium.

82-2240

Dynamic Analysis of a Large Structure with Artificial Damping

Q.L. Tian, D.K. Liu, Y.P. Li, and D.F. Wang

Inst. of Mech., Chinese Academy of Sciences, Beijing, China, Shock Vib. Bull. 52, Part 4, pp 147-153 (May 1982) 3 figs, 1 table, 10 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Damping effects, Dynamic response, Modal synthesis

A complex modal synthesis method is presented in this paper to analyze the dynamic response of a large structure with artificial damping.

82-2241

Hysteresis Models for Reinforced Concrete

M. Saiidi

Univ. of Nevada, Reno, NV 89557, ASCE J. Struc. Div., 108 (5), pp 1077-1087 (May 1982) 6 figs, 11 refs

Key Words: Concrete, Reinforced concrete, Hysteretic damping, Damping effects

Nonlinear dynamic response of a simple reinforced concrete specimen is studied using five different hysteresis models: the Takeda, elastoplastic, bilinear, Clough, and the Q-hyst model. These models range from simple but unrealistic (the elasto-plastic model) to complicated but realistic (the Takeda model). The Takeda model is used as the basis to evaluate the other models, and to explain the influence of different features used in each model.

82-2242

Acceleration and Deceleration of Single-Degree-of-Freedom Systems in Case of Critical Damping D = 1 (An- und Auslaufsvorgänge einfacher Schwinger im Kriechgrenzfall D = 1)

R. Markert

Institut f. Mechanik der Hochschule der Bundeswehr, Hamburg, W. Germany, Forsch. Ingenieurwesen, 48 (1), pp 11-14 (1982) 5 figs, 8 refs
(In German)

Key Words: Damping, Critical damping, Single degree of freedom systems

The vibrations of linear heteronomous single-degree-of-freedom systems during acceleration or deceleration were considered. An analytical solution was given, especially for critically damped systems D = 1. The right-hand side of the equation of motion is so universally represented, that all possible exciting mechanisms are included.

82-2243

Power Series Expansions for the Frequency and Period of the Limit Cycle of the Van Der Pol Equation

C.M. Andersen and J.F. Geer

Dept. of Math. and Computer Sci., College of William and Mary, Williamsburg, VA 23185, SIAM J. Appl. Math., 42 (3), pp 678-693 (June 1982) 7 figs, 5 tables, 15 refs

Key Words: Damping coefficients, Power series method, Van der Pol method

A power series expansion in the damping coefficient ϵ is developed for the frequency $\nu(\epsilon)$ of the limit cycle of the van der Pol equation $\ddot{U} + U = \epsilon\dot{U}(1 - U^2)$ $(0 \leq \epsilon < \infty)$. The expansion is computed to $O(\epsilon^{24})$ in rational arithmetic using the MACSYMA symbolic manipulation system and to $O(\epsilon^{164})$ in floating-point arithmetic using FORTRAN.

82-2244

Size Effect Related to Damping Caused by Water Submersion

R.G. Dong

Lawrence Livermore Lab., Univ. of California, Livermore, CA, Rept. No. CONF-810625-1 (Rev. 1), 13 pp (Jan 1981)

UCRL-80288 (Rev. 1)

Key Words: Damping coefficients, Viscous damping, Submerged structures, Underwater structures, Nuclear power plants, Seismic response

An important effect of water submersion on the dynamic response of a structure is the increase in effective damping. The dynamic response of submerged structures is of interest in the nuclear power industry for reasons of operational safety during seismic and other dynamic excitations. In this paper, the added damping contribution that results from the viscosity of water and the dependence of the contribution on structural size are examined. Other factors considered are the applicable range of viscous damping with respect to displacement amplitude and, as far as damping is concerned, how far neighboring members must be from each other to respond as if in open water.

82-2245

Maxwell Modelling in Structural Dynamics Including Stochastic Analysis

M.S. Skinner

Ph.D. Thesis, Univ. of California, Berkeley, 108 pp (1981)

DA8212108

Key Words: Damping coefficients, Maxwell modeling technique, Modal damping, Stochastic processes, Earthquake damage

A major part of this work is devoted to including the Maxwell model into stochastic analysis where probabilistic descriptions of inputs are used. This section is particularly related to earthquake engineering and results are presented which provide information about response from a wide range of input types. Response spectra methods are also investigated for use with the Maxwell model. In addition an appropriate technique is given for development of Maxwell spectra when only Kelvin-Voigt spectra are available. The Maxwell model is thus shown to be an appropriate model for many dynamic analyses of complex systems. Results necessary for application of both stochastic and spectra methods are given.

FATIGUE

(Also see No. 2159)

82-2246

The Effects of Endurance Limit and Crest Factor on Time to Failure under Random Loading

A.J. Curtis and S.M. Moite

Hughes Aircraft Co., Culver City, CA, Shock Vib. Bull. 52, Part 4, pp 21-24 (May 1982) 3 figs, 2 tables, 2 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Fatigue life, Random excitation

This paper is an extension of previous analyses by Miles, and by Curtis, Tinling and Abstein to determine the increase in average time to failure which may be expected due to the absence of stresses in excess of $\pm 3\sigma$ and the lack of fatigue damage for stress reversals less than the endurance limit.

82-2247

Fatigue Life Evaluation, Stochastic Loading, and Modified Life Curves

M. El Menoufy, H.H.E. Leipholz, and T.H. Topper

Dept. of Civil Engrg., Univ. of Waterloo, Waterloo, Ontario, Canada, Shock Vib. Bull. 52, Part 4, pp 11-19 (May 1982) 14 figs, 4 tables, 6 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Fatigue life, Steel, Random excitation

In this paper modified life curves have been introduced to facilitate the fatigue life predictions with sufficient accuracy for a material (Van-80 steel) subjected to stochastic loading programs with a finite number of strain levels. The Monte Carlo technique has been used to reproduce the load programs, and a number a tests have been performed. During the course of this investigation, it has come to light that the loading programs considered may not only in themselves have merit (as they may be appropriate models for practical situations of some significance) but that in addition they have great pedagogical value for anyone concerned with the development of a sound theory of stochastic fatigue.

82-2248

Fatigue Life Prediction for Various Random Stress Peak Distributions

R.G. Lambert

Aircraft Equipment Div., General Electric Co., Utica, NY 13503, Shock Vib. Bull. 52, Part 4, pp 1-10 (May 1982) 12 figs, 6 tables, 7 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Fatigue life, Random excitation

Closed form analytical expressions have been derived to predict the fatigue life for various random stress peak distributions. These distributions include the Rayleigh, exponential, truncated exponential, skewed Rayleigh, and finite sample size Rayleigh. Numerical examples of all expressions are worked out for a common structural aluminum alloy 7075-T6. The slopes of the resulting fatigue curves have application to accelerated random vibration test criteria.

82-2249

Fatigue Strength under Bi-Axial Out of Phase Vibrating Normal and Torsional Stresses (Schwingfestigkeitsverhalten unter zweiachsiger Beanspruchung mit phasenverschoben schwingenden Normal- und Schubspannungen

A. Troost, E. El-Magd, and S. Mielke

Aachen, Germany, Konstruktion, 34 (5), pp 197-202 (May 1982) 11 figs, 1 table, 11 refs
(In German)

Key Words: Fatigue life, Steel

The strength of 25Cr Mo4 steel under out of phase vibrating normal and torsional stresses is investigated. The experimental results show that, contrary to literature and earlier tests, the critical state of stress of 25Cr Mo4 steel and other materials can be calculated. By means of experiments with fixed stress times the authors try to show that the strength of material is affected by the orientation during main vibratory normal stresses.

82-2250

Experimental and Computational Determination of Life of Notched Flat Samples of St 45/60 at Multi-Stage Vibration Load (Experimentelle und rechnerische Bestimmung der Lebensdauer von gekerbten Flachproben aus St 45/60 bei mehrstufiger Schwingbelastung)

G. Schott and E. Wildfeuer

Technische Univ. Dresden, Sektion Grundlagen des Maschinenwesens, Bereich Werkstoffwissenschaft, Maschinenbautechnik, 31 (4), pp 179-183 (Apr 1982) 10 figs, 1 table, 4 refs
(In German)

Key Words: Fatigue life, Metals

A calculation method, based on a series of Wohler curves, was used for the determination of fatigue life of vibrating St 45/60 notched flat samples. Experimental results agree with theoretical results and prove that the method can be used for the determination of fatigue life of samples of various shapes and materials.

82-2251

A Comparison of Two Comparative Stress Hypotheses for Vibrating Loading with Experimental Results (Vergleich zweier Vergleichsspannungshypothesen für schwingende Beanspruchung mit experimentellen Ergebnissen)

J. Lensing

Universität Duisburg - GH, Fachgebiet Fördertechnik/Stahlbau, Bereich Betriebsfestigkeit, Germany, Kon-

struktion, 34 (2), pp 45-48 (Feb 1982) 6 figs, 1 table, 8 refs
(In German)

Key Words: Fatigue life

The shear stress intensity hypothesis for the calculation of fatigue strength of material subjected to alternating stress caused by periodic vibration is compared with the calculation of the comparative stress vibration amplitude σ_{Va} used in nuclear reactors (KTA regulations and ASME Pressure Code for Nuclear Vessels). The comparison shows that the shear stress intensity hypothesis is able to predict the critical results for the material under investigation, 34 or 4. However, if the excitation period (Spannungs zeitverlauf) is irregular, the method cannot be used. A calculation method for irregular excitation is given.

82-2252
Design of a Data Acquisition and Reduction System for Fatigue Testing
J.W. Dalton
Naval Postgraduate School, Monterey, CA, 64 pp (Sept 1981)
AD-A110 612

Key Words: Fatigue tests, Aircraft, Experimental test data, Data processing

A data acquisition and reduction system has been created for aircraft materials fatigue testing. The system uses an HP-9835 desktop calculator, an HP-2240A measurement and control processor and a materials testing system loading machine. Three different computer programs on the HP-9835 are used to analyze material properties, simulate in-flight fatigue loading and compute fatigue damage at a stress concentration. The flight loads are selected from Mil Spec 8866 and applied in a random order. The fatigue damage at a stress concentration is calculated from the applied local stresses using Miner's Law.

ELASTICITY AND PLASTICITY

82-2253
Recent Developments in Hygrothermoviscoelastic Analysis of Composites
T.J. Chung
Dept. of Mech. Engrg., The Univ. of Alabama in Huntsville, P.O. Box 1247, Huntsville, AL 35807,
Shock Vib. Dig., 14 (4), pp 33-40 (Apr 1982) 26 refs

Key Words: Composite structures, Viscoelastic properties, Environmental effects, Reviews

The physical phenomena associated with moisture diffusion and heat transfer in composite materials under static or dynamic loadings have been studied extensively in recent years. Objects of study include aircraft subjected to hostile weather during prolonged periods of service, moisture infiltration in solid rocket propellants, and loss of load carrying capacity in aerospace vehicles and components during heating, cooling, and moisture changes. This article reviews some recent advances in constitutive theories of hygrothermomechanical behavior of viscoelastic composites.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

(Also see No. 2220)

82-2254
Vibration of Some Structures with Periodic Random Parameters
W.-h. Huang
Harbin Inst. of Tech., Harbin, China, AIAA J., 20 (7), pp 1001-1008 (July 1982) 6 figs, 2 tables, 2 refs

Key Words: Spectrum analysis, Periodic structures, Random parameters, Blades, Turbomachinery blades, Natural frequencies

In a periodic structural system, such as blades in a closed packet of turbomachinery, the natural frequencies of the individual blades can be randomly different from one another. This paper describes a solution for such a periodic structure in which the distributions of blade frequencies are random processes with small standard deviations. A spectral method is suggested to solve differential equations with random coefficients. The expressions for vibration modes are given; the standard deviations of natural frequencies are estimated, and the results of forced vibration are presented. Some special features of vibration characteristics of this system are also shown.

82-2255
Practical Application of the Rapid Frequency Sweep Technique for Structural Frequency Response Measurement
R.G. White and R.J. Pinnington

Inst. of Sound and Vib. Res., Univ. of Southampton, UK, Aeronaut. J., 86 (855), pp 179-199 (May 1982) 19 figs, 23 refs

Key Words: Measurement techniques, Vibration analysis, Vibration measurement, Frequency response

The rapid frequency sweep technique is the result of a considerable amount of research into the development of a transient method for the rapid measurement of structural frequency response, digital data analysis procedures being used to derive the required dynamic characteristics. Theoretical analyses, together with the results of experimental studies and experience gained during structural testing are presented here which illustrate practical considerations and limitations of the method; these range from discussion of exciter attachment, effects of transducers and choice of instrumentation to signal processing methods and related criteria. A simple guide to practical structural testing is given in the final section which outlines procedures to be followed during testing and signal acquisition.

82-2256

Analysis of Measured Structural Frequency Response Data

M. Rades

Polytechnic Inst. Bucharest, Romania, Shock Vib. Dig., 14 (4), pp 21-32 (Apr 1982) 123 refs

Key Words: Measurement techniques, Computer-aided techniques, Vibration analysis, Vibration measurement, Frequency response data, Reviews

This article is concerned with computer-aided analysis of data obtained by single vibrator excitation and with the development of multi-vibrator excitation techniques.

82-2257

Measuring Vibrations for Coupling Evaluation

H. Schwerdlin and R.L. Eshleman

Lovejoy Inc., Downers Grove, IL, Plant Engrg., 36 (12), pp 111-114 (June 10, 1982) 4 figs, 6 refs

Key Words: Vibration measurement, Measuring instruments, Couplings

Vibration measurement equipment for evaluating and analyzing coupling performance is described. Coupling problems manifest themselves through lateral, axial and torsional vibrations -- the best sensor for each application is pointed out and suitable measurement locations are indicated. Proximity probes, magnetic pickups, strain gauges, velocity pickups and accelerometers are discussed and a variety of devices for analyzing the vibration signals are mentioned.

82-2258

D.C. Shift on Vibration Measurements in Nuclear Power Plants

D. DeLucchi

Wyle Labs., Huntsville, AL, J. Environ. Sci., 25 (3), pp 22-25 (May-June 1982) 10 figs, 3 refs

Key Words: Vibration measurement, Accelerometers, Nuclear power plants

Piezoelectric accelerometers and associated charge amplifiers or converters have been used to acquire vibration data at nuclear power plants for quite some time. During safety relief valve discharge tests, a DC shift has appeared at the beginning of some vibration and shock time histories. This paper was prepared to clarify why this phenomenon occurs and to suggest methods for correcting the problem.

82-2259

Angular-Vibration Measurement

P.C. Rymers

Univ. of Nevada, Reno, NV, Exptl. Techniques, 6 (3), pp 1-3 (June 1982) 1 fig, 1 table, 4 refs

Key Words: Vibration measurement, Measurement techniques, Laisers, Torsional vibration

The use of a laser in angular-vibration measurement has been demonstrated to be feasible when applied to a vibrating team. The measured results compare favorably with the computed values throughout all of the frequency parameters and bar-stiffness values where measurements were attempted.

82-2260

Registration of Three Soil Stress Gages at 0 through 28 MPa (4000 psi)

C.R. Welch

Corps of Engineers, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Shock Vib. Bull. 52, Part 3, pp 25-30 (May 1982) 6 figs, 3 refs

(Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Strain gages, Soils

A series of static tests were conducted on three soil stress gages. The gages tested were the currently accepted SE soil stress gage (34 MPa (5000 psi) range), a modified high range SE (HRSE) soil stress gage (138 MPa (20,000 psi) range), and the Waterways Experiment Station medium level (WML) stress gage. The tests consisted of multiple static loadings of two different soil types which contained four HRSE gages, four WML gages, and eight SE gages. Representative outputs from all three gage types are presented. The results imply that for dynamic tests in some soils the standard SE gage will indicate higher impulses than had actually occurred.

82-2261
Measurement of All Components of Strain by a 3-D Fiber Optic Strain Gage
S. Edelman and C.M. Davis, Jr.
Dynamic Systems, Inc., McLean, VA, Shock Vib. Bull. 52, Part 3, pp 19-24 (May 1982) 4 figs, 8 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Strain gages, Ground motion

This paper describes an instrument which has been designed but not yet built. A three-dimensional strain gage imbedded in the earth furnishes a complete description of the motions in the neighborhood of the gage. Fiber optic interferometers measure the three axial strains and the three shear strains at a point in terms of half-wavelengths of the laser light used. Arrays of such gages are suitable for geophysical exploration, earthquake studies, and studies of the effect of mechanical shocks on structures. The gage is sufficiently sensitive to monitor the motion of tectonic plates.

DYNAMIC TESTS
(Also see No. 2114)

82-2262
Digital Control of a Shaker to a Specified Shock Spectrum
J.F. Unruh
Southwest Res. Inst., San Antonio, TX, Shock Vib. Bull. 52, Part 3, pp 1-9 (May 1982) 9 figs, 6 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Shakers, Test equipment and instrumentation, Seismic response, Nuclear power plants, Nuclear reactor components, Computer-aided techniques

A digital computer based control system was developed for a biaxial electrohydraulic shaker table used for seismic qualification testing of nuclear power plant components. The system drive signals were developed from a weighted linear sum of 1/6-octave psuedo random noise signals. Preliminary drive signal shaping is accomplished through the use of a series of table mounted dummy mass transfer functions obtained from a previously generated data bank. Adjustments to the drive signal are made by direct comparison of the resulting test response spectrum to the required response spectrum. Drive signal shaping sequences for a 2000 lb electrical equipment control cabinet are presented to demonstrate the effectiveness of the control system for seismic qualification.

82-2263
The Changing Dimensions of Qualification Testing
H.N. Abramson
Southwest Res. Inst., 6220 Culebra Rd., San Antonio, TX 78284, Shock Vib. Dig., 14 (4), pp 3-19 (Apr 1982) 20 figs, 27 refs (Reprinted from Shock Vib. Bull. 52, Part 1, pp 35-48 (May 1982))

Key Words: Dynamic tests, Testing techniques, Nuclear power plants, Reviews

The purpose of this paper is to demonstrate the changing dimensions of qualification testing in the interests of both the DOD and the nuclear power industry. In the one case the objective is mission integrity. It is achieved principally through generic testing; that is, the environment is a stable one. In the other case, the objective is operational reliability. It is achieved mostly through custom testing; that is, the environment is an unstable one.

82-2264
Studies on Evaluation of Shaking Table Response Analysis Procedures
S.J.M. Blondet

Ph.D. Thesis, Univ. of California, Berkeley, 196 pp (1981)
DA8211862

Key Words: Shakers, Reinforced concrete, Seismic response

This dissertation is divided in two separate but related parts. In Part A the evolution of the response of reinforced concrete frames to seismic ground motions was studied using experimental data recorded during shaking table experimentation of a reinforced concrete model structure. The objective of Part B of the research was to study numerical methods for filtering shaking table and seismic signals in order to reliably perform certain operations such as integration of acceleration records to evaluate the corresponding velocity and displacement.

DIAGNOSTICS

82-2265

Modal Analysis as a Tool in the Evaluation of a Turbine Wheel Failure

A.L. Moffa and R.L. Leon

Franklin Res. Ctr., Philadelphia, PA, Shock Vib. Bull. 52, Part 1, pp 101-123 (May 1982) 23 figs, 5 tables, 3 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Diagnostic techniques, Turbine components, Wheels, Modal analysis

Following a turbine wheel failure, the system is taken out of service, the failed parts are metallurgically analyzed, and the turbine is either repaired or replaced. It is during this often lengthy time period that modal testing can be performed and its evaluation used to aid in the failure analysis. Guidelines, helpful in this endeavor, are listed. This paper follows these guidelines, and illustrates by techniques, examples, and actual test data how modal analysis can play an important part in failure evaluation.

82-2266

Machinery Vibration Evaluation Techniques

R.L. Eshleman

Vibration Inst., Clarendon Hills, IL, Shock Vib. Bull. 52, Part 1, pp 67-79 (May 1982) 19 figs, 2 tables, 9 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Diagnostic techniques, Machinery vibration, Frequency analysis, Time domain method, Frequency domain method

Direct frequency analysis of vibration signals is commonly used to evaluate the condition of machinery. This paper is concerned with this technique, its variations, and many other techniques available for machinery vibration evaluation. The techniques described and illustrated in this paper involve the time and frequency domains, orbital motions, transient tests, and parameter analyses -- either calculated or measured.

82-2267

Shaft Vibration Measurement and Analysis Techniques

D.E. Bently

Bently Nevada Corp., Minden, NV, Shock Vib. Bull. 52, Part 1, pp 81-93 (May 1982) 7 figs, 3 tables (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Diagnostic instrumentation, Shafts, Vibration measurement, Vibration analysis

The use of electronic instrumentation for the measurement and analysis of rotating machinery has advanced greatly over the last fifteen years. Of the available vibration measurement transducers, the displacement proximity probe is most widely used on critical equipment. However, there are still some applications for the case-mounted transducers, velocity sensors, and accelerometers. For the purpose of machinery analysis, several hard copy data presentations are available. Data formats for steady-state machine conditions include oscilloscope time base waveforms and orbits and frequency spectra. For data from machines under transient conditions, the formats include Polar, Bode', cascade or waterfall plots, and change in average shaft centerline position.

82-2268

Single Point Random Modal Test Technology Application to Failure Detection

W.M. West, Jr.

Lyndon B. Johnson Space Ctr., Houston, TX, Shock Vib. Bull. 52, Part 4, pp 25-31 (May 1982) 16 figs, 1 table (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Diagnostic techniques, Failure detection, Space shuttle, Modal tests, Frequency response function

The information contained in this paper demonstrates that frequency response function data, normally acquired as a data base for use in development of empirically based mode shapes, has additional utility. Comparison and analysis of frequency response function data sets obtained prior to and after environmental tests of an Orbiter body flap have enabled identification of structural damage that had not been detected by conventional visual, X-ray, and ultrasonic inspections. The analyses and conclusions reported in this paper demonstrate that specific damaged areas within a relatively complex structure can be identified on a timely basis.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

82-2269

Self-Excited Vibration of a Nonlinear System with Random Parameters

R.A. Ibrahim

Dept. of Mech. Engrg., Texas Tech Univ., Lubbock, TX 79409, Shock Vib. Bull. 52, Part 1, pp 135-144 (May 1982) 3 figs, 23 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Nonlinear systems, Single degree of freedom systems, Machine tools, Fluid film bearings, Self excited vibration, Random parameters

This paper deals with the dynamic behavior of a nonlinear single degree-of-freedom system with negative linear damping and subjected to broadband random excitations. The system response is analyzed by using two different approaches: the Stratonovich stochastic averaging method, and the Ito stochastic calculus together with the Gaussian closure. Closed-form solutions of the stationary responses are obtained.

82-2270

Finite Elements for Initial Value Problems in Dynamics

T.E. Simkins

Benet Weapons Lab., Large Caliber Weapon Sys. Lab., U.S. Army Armament Res. and Dev. Command, Watervliet, NY 12189, Shock Vib. Bull. 52, Part 5, pp 39-48 (May 1982) 2 figs, 2 tables, 24 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Initial value problems, Finite element techniques, Time domain method

The complete dynamic analysis of shock and vibration problems usually requires the solution of one or more hyperbolic partial differential equations involving space and time as independent variables. Many times a numerical solution is attempted by first eliminating the spatial dependency through the substitution of Ritz type approximations into a variational formulation of the problem, thus generating a corresponding set of ordinary differential equations in time; i.e., the Euler-Lagrange equations for the problem. The solution of these equations can sometimes be tedious owing to the hyperbolic nature of the problem. The difficulties encountered and their logical resolution leading to a workable finite element formulation for the time domain is the main topic of this paper. A few demonstrations of the utility of finite elements in time are also given.

82-2271

Determination of Normal Modes from Measured Complex Modes

S.R. Ibrahim

Dept. of Mech. Engrg. and Mech., Old Dominion Univ., Norfolk, VA 23508, Shock Vib. Bull. 52, Part 5, pp 13-17 (May 1982) 3 figs, 2 tables, 15 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Normal modes, Experimental test data

A technique is presented to compute a set of normal modes from a set of measured complex modes. The number of elements in the modal vectors, which is equal to the number of measurements, can be larger than the number of modes under consideration. It is also shown that the practice of normal mode approximation to complex modes can lead to very large errors when the modes are too complex. A numerical example and a simulated experiment are presented to illustrate the concepts discussed and to support the theory presented.

82-2272

Forced Vibrations of a Large Damped Mechanical System

D.W. Nicholson

Naval Surface Weapons Ctr., White Oak, Silver Spring, MD 20910, Shock Vib. Bull. 52, Part 4, pp 33-36 (May 1982) 1 fig, 4 refs (Proc. 52nd Symp. on Shock and Vib., New Orleans, LA, Oct 26-28, 1981. Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Mechanical systems, Damped structures, Forced vibration

Recently the author extended a theorem of Strang to derive a function whose extreme values gives bounds on the forced response of a damped mechanical system. Here the derivation is briefly reviewed, the numerical algorithm for its computation is presented, and some computational results are given which show the expected trend.

82-2273

Spectral Analysis of Non-Linear Systems Involving Square-Law Operations

J.S. Bendat and A.G.Piersol

J.S. Bendat Co., 833 Moraga Drive, Los Angeles, CA 90049, J. Sound Vib., 81 (2), pp 199-213 (Mar 22, 1982) 9 figs, 8 refs

Key Words: Spectrum analysis, Frequency domain method, Random excitation, Nonlinear systems

This paper contains a number of useful theoretical formulas to analyze the frequency domain properties of Gaussian input data passing through nonlinear square-law systems. Special bispectral density functions are defined and applied that are functions of a single variable. From measurements of input data and output data only, results are obtained to identify the separate frequency response functions for two models of linear systems in parallel with nonlinear square-law systems.

82-2274

Modern Data Analysis Techniques in Noise and Vibration Programs

Advisory Group for Aerospace Res. and Dev., Neuilly-sur-Seine, France, Rept. No. AGARD-R-700, 167 pp (Nov 1981)
AD-A111 490

Key Words: Noise reduction, Vibration control, Data processing

Partial contents are as follows: Methodes Modernes d'Analyse et de Traitement du Signal Utilisees en Acoustique et Vibration et Appliquees a l'Aeroacoustique; Fluctuating Stress Fields in Continuous Media; Vibration of Structures Excited Acoustically; Fundamental Concepts of Sound Radiation: Fundamental Concepts of Flow-Generated Noise; Extended Sound Sources; Stochastic Excitation of Elastic Structures and Examples of Flow-Generated Noise; Sound Radiation by Elastic Structures; The Application of Statistical Energy Analysis to Vibration of Structures Excited Acoustically; Linear Signal Processing; Linear Signal Processing II; Non-Stationarity and Nonlinearity in Data Analysis; Parametric Methods in Signal Analysis; Vibration Transmission and Sound Radiation; Procedures Relating the Near to the Far-Field -- Imaging Techniques; Progres Recents dans la Mesure de l'Intensite Acoustique; and Modal Analysis Using Digital Test Equipment.

82-2275

Response of MDOF Systems to Vector Random Excitation

A. DebChaudhury and D.A. Gasparini

Dept. of Materials Engrg., Univ. of Illinos at Chicago Circle, Chicago, IL 60680, ASCE J. Engrg. Mech. Div., 108 (2), pp 367-385 (Apr 1982) 8 figs, 1 table, 6 refs

Key Words: Multidegree of freedom systems, Random excitation, Modal analysis

A modal time history random vibration analysis is presented. The random excitation is nonwhite, nonstationary, vector-valued and correlated. Excitation components may have different frequency contents and variations in intensity with time. The correlation between any two components can be a function of time. The formulation is appropriate for any linear MDOF system which has been decoupled into modes. Analytical expressions are derived for the evolutionary mean and covariance matrices of a modal system augmented by filters and subjected to vector-valued excitation having piece-wise linear strength functions. Using modal superposition, evolutionary mean and covariance matrices of any response vector are computed. A three degree-of-freedom system, subjected to vector-valued earthquake excitation, is analyzed. The formulation captures the effects of nonstationarity and correlation between earthquake components.

82-2276

A Finite Element Method for Elastoimpact Contact Structures with Translational Motion

N. Asano

Dept. of Mech. Engrg., Tamagawa Univ., Machida, Tokyo, Japan, Bull. JSME, 25 (202), pp 501-507 (Apr 1982) 7 figs, 10 refs

Key Words: Finite element technique, Impact response, Machinery components

A finite element method applicable to an analysis of elastoimpact contact structures with a translational motion is formulated by use of the virtual work principle for two elastoimpact bodies in a contact state. The method is applied to a two-dimensional behavior for longitudinal impact of two uniform rods with an equal cross section. Although the contact stresses by the method fluctuate periodically due to the lateral effect of inertia, their mean value agrees well with that by the theory of propagation of a one-dimensional elastic stress wave. The stick, slip and separate states on the impact surface between the two rods is also investigated. Hence the use of the method makes it possible to calculate contact and separate states of various elastoimpact contact structures.

MODELING TECHNIQUES

(Also see Nos. 2140, 2142)

82-2277

Sensitivity Analysis and Model Identification in Simulation Studies: A Frequency Domain Approach

V.J. Cogliano

Ph.D. Thesis, Cornell Univ., 174 pp (1982)
DA8210805

Key Words: Simulation, Frequency domain method

A new approach is presented for sensitivity analysis and model identification in simulation studies. A frequency domain approach is taken, in which the parameters oscillate during a run of the simulation model instead of remaining constant throughout the run. The terms present in a polynomial model of the response are indicated by changes in the frequency spectrum of the response. This approach can be used as a screening tool for quickly focusing attention on the few most important parameters and as an aid in designing experiments to estimate the response model coefficients and to study the system further.

NUMERICAL METHODS

82-2278

Numerical Techniques for Solving Nonlinear Instability Problems in Solid Rocket Motors

J.D. Baum and J.N. Levine

Univ. of Dayton, Dayton, OH, AIAA J., 20 (7), pp 955-961 (July 1982) 11 figs, 23 refs

Key Words: Numerical methods, Solid propellant rocket engines, Stability analysis, Shock wave propagation

The results of an investigation to select a satisfactory numerical method for calculating the propagation of steep-fronted, shock-like waveforms in a solid rocket motor combustion chamber are presented. A number of different numerical schemes were evaluated by comparing the results obtained for three related but simpler problems: the shock-tube problem, the linear wave equation, and nonlinear wave propagation in a closed tube.

PARAMETER IDENTIFICATION

82-2279

Determination of System Parameters of Linear Oscillators by Means of Modal Analysis (Ermittlung der Systemparameter ... Schwinger mit Hilfe der modalen Analyse)

J. Lücke

Technische Hochschule Otto von Guericke Magdeburg, Sektion Maschinenbau, Maschinenbautechnik, 31 (5), pp 201-203 (May 1982) 2 figs, 3 tables, 7 refs
(In German)

Key Words: Parameter identification technique, Modal analysis, Error analysis

A parameter identification technique for mechanical systems is presented which employs measured input and ouput time function for a modal analysis of the system. The object of the investigation is to show that the measurement errors of frequency response can be calculated and thus eliminated. In addition, a frequency response smoothing is presented.

82-2280

Estimation of Stationary Structural System Parameters from Non-Stationary Random Vibration Data: A Locally Stationary Model Method

W. Gersch and T. Brotherton

Dept. of Information and Computer Sciences, Univ. of Hawaii, Honolulu, HI, J. Sound Vib., 81 (2), pp 215-227 (Mar 22, 1982) 4 figs, 2 tables, 19 refs

Key Words: Parameter identification technique, Buildings, Natural frequencies, Damping coefficients

Stationary structural system (building) natural frequency and damping parameters are estimated from a long non-stationary ambient vibration time series record. The non-stationary vibration record is decomposed into continuous, not necessarily equal duration, stationary time series segments by a locally stationary autoregressive (AR) model method. Estimates of the stationary structural system parameters are extracted from each of the locally stationary AR models. The results of the analysis of a long duration non-stationary record are compared with the results of an earlier approach in which the long duration non-stationary record was decomposed into relatively short fixed duration vibration records and analyzed as stationary time series.

DESIGN TECHNIQUES

82-2281

Three-Dimensional Dynamic Analysis for Multi-Component Earthquake Spectra

E.L. Wilson and M.R. Button

Univ. of California, Berkeley, Earthquake Engrg. Struc. Dynam., 10 (3), pp 471-476 (May-June 1982) 3 figs, 4 tables, 7 refs

Key Words: Seismic design, Three dimensional problems

At the present time there is a need for a rational approach for the analysis and design of three-dimensional structures subjected to multi-component earthquake motions. In this paper, a general design criterion for multi-component earthquake input is proposed. A new method for three-dimensional dynamic analysis is presented which estimates maximum displacements, forces or stresses for specified points within a structure.

COMPUTER PROGRAMS

(Also see No. 2128)

82-2282

FEMROT – A Program for Calculation of Rotor Oscillations (FEMROT – ein Programm zur Berechnung von Rotorschwingungen)

E. Pausch and D. Waldeck

Technische Hochschule Karl-Marx-Stadt, Sektion Maschinen-Bauelemente, Maschinenbautechnik, 31 (5), pp 204-209 (May 1982) 5 figs, 9 refs (In German)

Key Words: Computer programs, Finite element technique, Beams, Springs, Damping effects, Rotating structures

The program FEMROT uses finite beam elements, discrete spring elements and damping elements proportional to velocity as components of modeling. It allows to consider the inertial properties of non-rotating and rotating rigid bodies. By means of this program static deformations, free and forced oscillations and starting responses at a given time of angular velocity can be calculated.

GENERAL TOPICS

CONFERENCE PROCEEDINGS

82-2283

Nondestructive Evaluation of Turbines and Generators: 1980 Conference and Workshop

R.H. Richman and T. Rettig

Aptech Engrg. Services, Inc., Palo Alto, CA, Rept. No. EPRI-WS-80-133, CONF-8010213, 569 pp (July 1981)

DE81904217

Key Words: Proceedings, Turbines, Generators

This report contains formal presentations and results of four workshop sessions on the nondestructive evaluation (NDE) of steam turbines and generators. The workshop was directed at utility problems in turbine-generator evaluation and in making repair or run-retire decisions. Areas of concentration include industry problems, turbine NDE, generator NDE, EPRI projects, vibration signature analysis, and new developments.

82-2284

Noise and Vibrations of Engines and Transmissions

IMechE Conference Publications 1979-10. Conference spons. by Automobile Div. and the School of Automotive Studies of the Institution of Mechanical Engineers, held at the Cranfield Institute of Technology, July 10-12, 1979. Publ. by IMechE 1979.

Key Words: Proceedings, Automobile engines, Automotive transmissions, Engine noise, Engine vibration, Vibration control, Fatigue life, Noise reduction

The eighteen papers presented at this conference deal with the problems of environmental noise pollution in the light of meeting the more demanding requirements contained in recent legislation restricting noise levels. Papers cover the fields of fatigue failure, vibration related to wear, and other general problems related to noise and vibration in engines and transmissions.

TUTORIALS AND REVIEWS

(See No. 2161)

AUTHOR INDEX

CALENDAR

NOVEMBER 1982

8-10 Intl. Modal Analysis Conference [Union College] Orlando, FL *(Prof. Raymond Eisenstadt, Union College, Graduate and Continuing Studies, Wells House, 1 Union Ave., Schenectady, NY 12308 - (518) 370-6288)*

8-12 Acoustical Society of America, Fall Meeting [ASA] Orlando, FL *(ASA Hqs.)*

8-12 Truck Meeting & Exposition [SAE] Indianapolis, IN *(SAE Hqs.)*

14-19 American Society of Mechanical Engineers, Winter Annual Meeting [ASME] Phoenix, AZ *(ASME Hqs.)*

DECEMBER 1982

14-16 11th Turbomachinery Symposium [Texas A&M University] Houston, TX *(Peter E. Jenkins, Turbomachinery Labs., Dept. of Mech. Engrg., Texas A&M Univ., College Station, TX 77843 - (713) 845-7417)*

FEBRUARY 1983

28 - Mar 4 SAE Congress & Exposition [SAE] Detroit, MI *(SAE Hqs.)*

MARCH 1983

21-23 NOISE-CON 83 [Institute of Noise Control Engineering] Cambridge, MA *(NOISE-CON 83, Massachusetts Inst. of Tech., Inst. Information Services, 77 Massachusetts Ave., Cambridge, MA 02139 - (617) 253-1703)*

28-31 Design Engineering Conference and Show [ASME] Chicago, IL *(ASME Hqs.)*

APRIL 1983

18-20 Materials Conference [ASME] Albany, NY *(ASME Hqs.)*

18-21 Institute of Environmental Sciences' 29th Annual Technical Meeting [IES] Los Angeles, CA *(IES, 940 E. Northwest Highway, Mount Prospect, IL 60056 - (312) 255-1561)*

21-22 14th Annual Modeling and Simulation Conference [Univ. of Pittsburgh] Pittsburgh, PA *(William G. Vogt, Modeling and Simulation Conf., 348 Benedum Engineering Hall, Univ. of Pittsburgh, Pittsburgh, PA 15261)*

MAY 1983

9-13 Acoustical Society of America, Spring Meeting [ASA] Cincinnati, OH *(ASA Hqs.)*

9-13 Symposium on Interaction of Non-Nuclear Munitions with Structures [U.S. Air Force] Colorado Springs, CO *(Dr. C.A. Ross, P.O. Box 1918, Eglin AFB, Florida 32542 - (904) 882-5614)*

JUNE 1983

6-10 Passenger Car Meeting [SAE] Dearborn, MI *(SAE Hqs.)*

20-22 Applied Mechanics, Bioengineering & Fluids Engineering Conference [ASME] Houston, TX *(ASME Hqs.)*

JULY 1983

11-13 13th Intersociety Conference on Environmental Systems [SAE] San Francisco, CA *(SAE Hqs.)*

AUGUST 1983

8-11 Computer Engineering Conference and Exhibit [ASME] Chicago, IL *(ASME Hqs.)*

8-11 West Coast International Meeting [SAE] Vancouver, B.C. *(SAE Hqs.)*

SEPTEMBER 1983

11-13 Petroleum Workshop and Conference [ASME] Tulsa, OK *(ASME Hqs.)*

11-14 Design Engineering Technical Conference [ASME] Dearborn, MI *(ASME Hqs.)*

12-15 International Off-Highway Meeting & Exposition [SAE] Milwaukee, WI *(SAE Hqs.)*

14-16 Intl. Symposium on Structural Crashworthiness [University of Liverpool] Liverpool, UK *(Prof. Norman Jones, Dept. of Mech. Engrg., The Univ. of Liverpool, P.O. Box 147, Liverpool L69 3BX, England)*

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS: American Federation of Information Processing Societies
210 Summit Ave., Montvale, NJ 07645

AGMA: American Gear Manufacturers Association
1330 Mass Ave., N.W.
Washington, D.C.

AHS: American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics, 1290 Sixth Ave.
New York, NY 10019

AIChE: American Institute of Chemical Engineers
345 E. 47th St.
New York, NY 10017

AREA: American Railway Engineering Association
59 E. Van Buren St.
Chicago, IL 60605

ARPA: Advanced Research Projects Agency

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
345 E. 45th St.
New York, NY 10017

ASME: American Society of Mechanical Engineers
345 E. 45th St.
New York, NY 10017

ASNT: American Society for Nondestructive Testing
914 Chicago Ave.
Evanston, IL 60202

ASQC: American Society for Quality Control
161 W. Wisconsin Ave.
Milwaukee, WI 53203

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

CCCAM: Chairman, c/o Dept. ME, Univ. Toronto,
Toronto 5, Ontario, Canada

ICF: International Congress on Fracture
Tohoku Univ.
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IFToMM: International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
400 Stanwix St.
Pittsburgh, PA 15222

ONR: Office of Naval Research
Code 40084, Dept. Navy
Arlington, VA 22217

SAE: Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

SEE: Society of Environmental Engineers
6 Conduit St.
London W1R 9TG, UK

SESA: Society for Experimental Stress Analysis
21 Bridge Sq.
Westport, CT 06880

SNAME: Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE: Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC: Shock and Vibration Information Center
Naval Research Lab., Code 5804
Washington, D.C. 20375

URSI-USNC: International Union of Radio Science - U.S. National Committee
c/o MIT Lincoln Lab.
Lexington, MA 02173

PUBLICATION POLICY

Unsolicited articles are accepted for publication in the Shock and Vibration Digest. Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in DIGEST articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the example below.

> Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].
>
> Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that . . .

The format and style for the list of References at the end of the article are as follows:

- each citation number as it appears in text (not in alphabetical order)
- last name of author/editor followed by initials or first name
- titles of articles within quotations, titles of books underlined
- abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)
- volume, number or issue, and pages for journals; publisher for books
- year of publication in parentheses

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter - A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).

2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addision-Wesley (1955).

3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Devel. (1962).

4. Lin, C.C., Reissner, E., and Tsien, H., "On Two-Dimensional Nonsteady Motion of a Slender Body in a Compressible Fluid," J. Math. Phys., 27 (3), pp 220-231 (1948).

5. Landahl, M., Unsteady Transonic Flow, Pergamon Press (1961).

6. Miles, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," J. Aeronaut. Sci., 23 (7), pp 671-678 (1956).

7. Lane, F., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," J. Aeronaut. Sci., 24 (1), pp 65-66 (1957).

Articles for the DIGEST will be reviewed for technical content and edited for style and format. Before an article is submitted, the topic area should be cleared with the editors of the DIGEST. Literature review topics are assigned on a first come basis. Topics should be narrow and well-defined. Articles should be 1500 to 2500 words in length. For additional information on topics and editorial policies, please contact:

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